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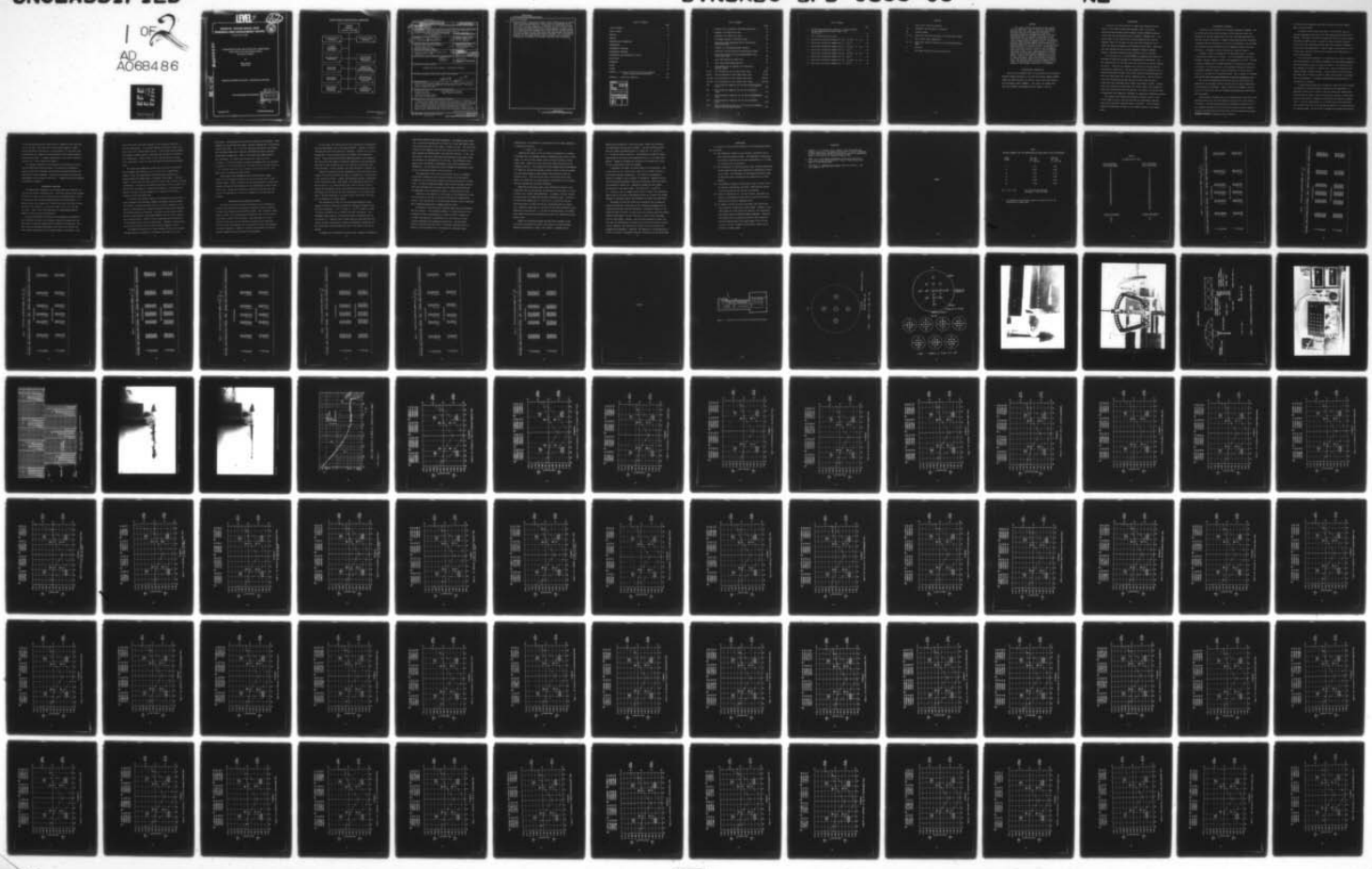

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

CALIBRATION OF 5-HOLE AND 13-HOLE PITOT TUBES BEFORE AND AFTER A FULL-SCALE WAKE SURVEY ON THE R/V ATHENA

by

Rae B. Hurwitz
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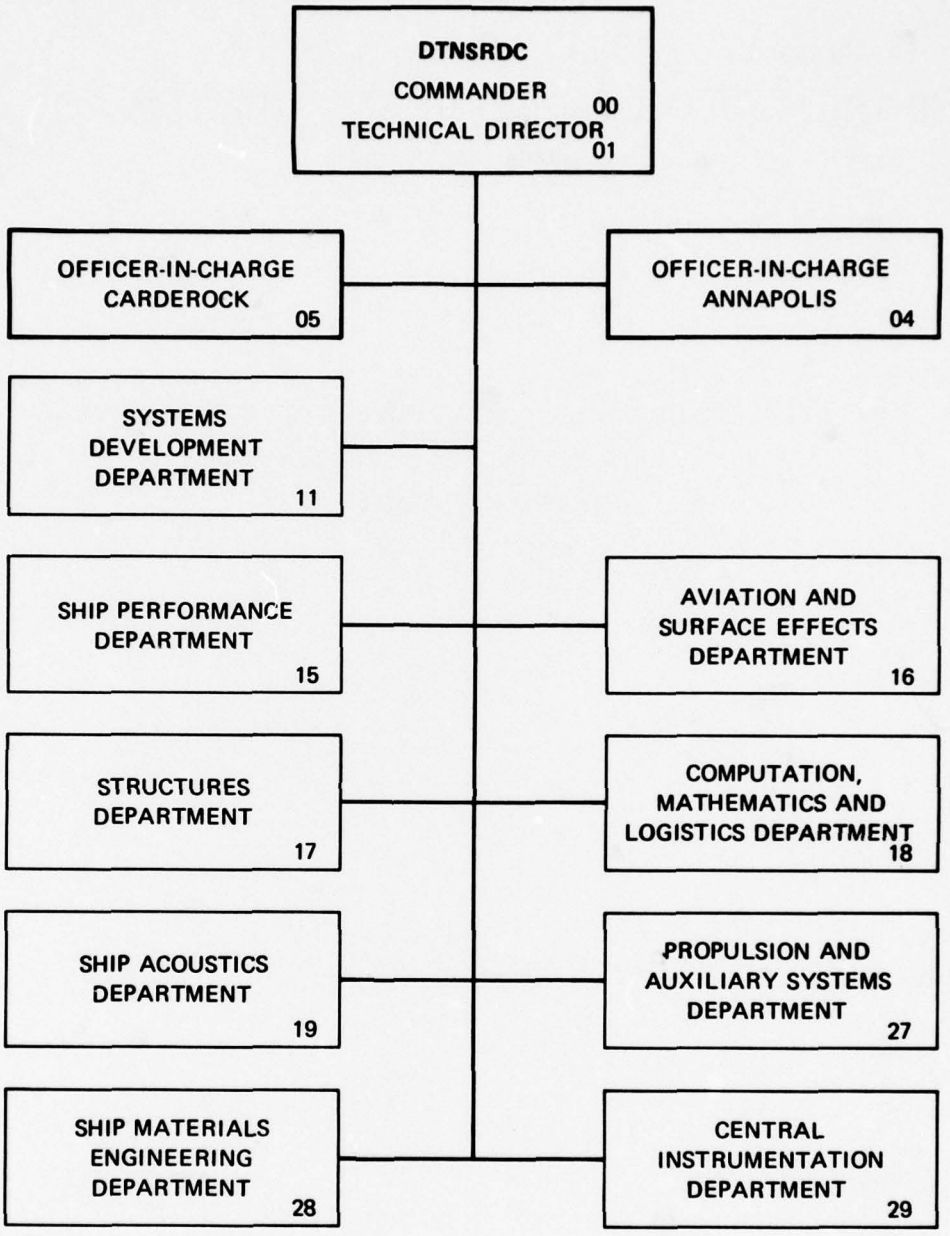

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This report presents the results of the calibrations of spherical 5- and 13-hole pitot tubes before and after they were used in a full-scale wake survey. Brief descriptions of standard and specifically developed calibration instrumentation and of calibration procedures are included. The purpose of the calibrations was to determine differential pressure ratios which, during a full-scale wake survey, could be used to compute velocity

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component ratios. Differential pressure ratios obtained during the calibrations are depicted graphically in terms of angle of inclination for the pitot tubes at 20 fps (6.10 m/s). In addition, one 5-hole pitot tube was run at four velocities ranging from 6 to 25 fps (1.83 to 7.62 m/s). The calibrations were shown to have a small speed dependence at higher speeds but a significant speed dependence at the lower speeds. Finally, the composite test results for the 5-hole pitot tubes were analyzed statistically to obtain the means, spreads and tolerance intervals. Due to the observed spread of the data among different tubes, the application of individual calibrations, as opposed to one average calibration, was recommended.

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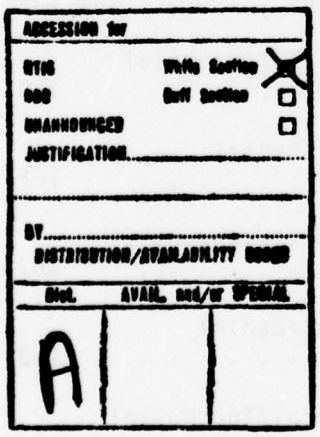

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NOTATION

C	Center pitot tube hole pressure
P{}	Probability of the event {} occurring
Rn	Reynolds number
R_1, R_2	Outer pitot tube hole pressure in vertical/radial plane
T	Sea or basin water temperature
T_1, T_2	Outer pitot tube hole pressure in horizontal/tangential plane
V	Velocity
β	Flow angle from the pitot tube center hole

ABSTRACT

This report presents the results of the calibrations of spherical 5- and 13-hole pitot tubes before and after they were used in a full-scale wake survey. Brief descriptions of standard and specifically developed calibration instrumentation and of the calibration procedure are included. The purpose of the calibrations was to determine differential pressure ratios which, during a full-scale wake survey, could be used to compute velocity component ratios. Differential pressure ratios obtained during the calibrations are depicted graphically in terms of angle of inclination for the pitot tubes at 20 fps (6.10 m/s). In addition, one 5-hole pitot tube was run at four velocities ranging from 6 to 25 fps (1.83 to 7.62 m/s). The calibrations were shown to have a small speed dependence at higher speeds but a significant speed dependence at the lower speeds. Finally, the composite experimental results for the 5-hole pitot tubes were analyzed statistically to obtain the means, spreads and tolerance intervals. Due to the observed spread of the data among different tubes, the application of individual calibrations, as opposed to one average calibration, was recommended.

ADMINISTRATIVE INFORMATION

This work was performed under the Controllable Pitch Propeller Research Program sponsored by the Naval Sea Systems Command (NAVSEA 0331G) and administered by the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). The project was funded under Task Area S0379001 and DTNSRDC Work Unit Number 1-1524-641.

INTRODUCTION

As part of its overall project to adapt controllable pitch propellers to the needs of high speed combatant ships, the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) conducted a full-scale wake survey aboard the R/V ATHENA in September 1977. The specific goal of this project was to obtain propeller disk velocity component ratios in the wake of a full-scale ship through the use of 5-hole and specially designed 13-hole spherical pitot tubes. Additional data were derived from the velocity components through a harmonic analysis, from which propeller design criteria could be verified.

Chi Associates, Inc. assisted DTNSRDC in performing the analysis of experimental data from two types of instrumentation calibrations. One was conducted prior to the full-scale wake survey and the second following the survey. These will be referred to in the text as the pre and post calibrations, respectively. The basic purpose of the calibrations was to measure differential pressure ratios which could be converted during the full-scale wake survey into velocity component ratios. The pre calibrations were conducted during June and July of 1977, while the post calibrations were performed during January and February of 1978. Calibrations were conducted at known angles for several speeds, and calibration curves were plotted from the data gathered. The results of these two sets of experiments were compared to determine if significant differences existed.

This report gives background information relevant to both 5- and 13-hole spherical pitot tubes and describes the experimental apparatus used and the procedures employed during calibration. It also contains figures and appendices relevant to the technical details of the experiments.

EXPERIMENTAL APPARATUS

Calibrations were conducted on the towing carriages at DTNSRDC. The pre calibration utilized both Carriage 2 of the Deep Water Basin and Carriage 5 of the High Speed Basin, while only the High Speed Basin was used for the post calibration. Though it would have been more convenient to operate from one carriage for both series of experiments, two carriages were used for the pre calibration due to scheduling conflicts and time constraints. Schematics of the two basins are shown in Figure 1.

Carriage 2, which is mounted over the Deep Water Basin, is capable of operating at speeds up to 20 knots. Its electrohydraulic drive can maintain carriage speeds to within a few hundredths of a knot. Carriage 5, which is mounted over the High Speed Basin, can operate at speeds up to 55 knots. The electric drive is an adjustable voltage DC system with an automatic feedback control, which can regulate the steady speed to within $\pm$ 0.1 percent of its prescribed value. Both carriages are equipped with digital data acquisition systems for collecting experimental data.

Most of the instrumentation in the pre and post calibrations was supplied by the Department of Naval Architecture and Marine Engineering at the University of Michigan. Some of the special equipment, particularly the 13-hole pitot tube, was designed and manufactured specifically for this project.

The principal instrument used in the calibration was the 5-hole brass spherical pitot tube, 19 inches (483 mm) long and 2.375 inches (60 mm) in diameter. Detailed design features are presented in Troesch et al.[1*] and a graphic description of the 5-hole pitot tube is given in Figure 2. It can be seen that each of the four holes used for measuring the angles

*Complete listing of references given on page 13.

has been drilled 30 degrees away from the center hole and 90 degrees apart from one another.

In addition to the 5-hole pitot tube, a 13-hole pitot tube was specially designed for the full scale wake survey and was calibrated at DTNSRDC. This pitot tube differs considerably from the classical design described by Janes[2] in that it consists of seven partially redundant 5-hole pitot tube combinations rather than three completely redundant 5-hole pitot tube combinations. Figure 3 depicts the design of the new 13-hole pitot tube and illustrates the seven possible combinations of 5-hole configurations.

The pitot tube was mounted on a calibration jig, shown in Figure 4, which was moveable in five degree increments in the horizontal/tangential and vertical/radial planes, as shown in Figure 5. The calibration jig was suspended on a funnel or inverted cone, which was fastened to the towing carriage structure (bridge). A spacer plate was placed between the funnel and the bridge in order to lower the pitot tube to the proper level of submergence. A schematic showing general design features is included here as Figure 6.

A single pressure gauge with a Scanivalve system was used to measure the pressure in each hole during the running of the experiments. An important feature of this system is that the Scanivalves automatically close off the air bleed. Once the carriage has attained a steady speed, the pitot tube system is manually activated and then operates automatically. Initially, pressurized air is ejected from the pressure tanks. This blows all water out of the system and registers as a high plateau on the pressure gauge. The air bleed is automatically stopped and pressure

in the system decreases until equilibrium is reached for the total pressure of the flow. This registers on the pressure gauge as a rapid decline followed by transition to a lower plateau. At this point, the system signals the computer that equilibrium has been reached and data collection can begin. A complete description of the system is given in Troesch et al.[1] and is depicted in Figure 7.

An Interdata computer was used during the calibrations to collect the data onboard the towing carriage, to calculate the differential pressure ratios and to generate the calibration coefficients after the experiments had been completed. Strip chart recordings of the pressure measurements were also made for each tube. A sample strip chart recording is presented in Figure 8.

EXPERIMENTAL PROCEDURE

The experimental procedures in the towing tanks were identical for both the pre and post calibration runs. Each pitot tube was towed through the water at 20 fps (6.10 m/s) with its axis at different angles in each of two planes, the horizontal/tangential and the vertical/radial. In addition, tube 13 was towed at 6, 11 and 25 fps (1.83, 3.35 and 7.62 m/s) and tube 37 was towed at 6, 11, 25 and 30 fps (1.83, 3.35, 7.62, and 9.14 m/s). Table 1 lists each speed and its corresponding Reynolds number for the pre and post calibrations.

For each calibration, the pitot tube was mounted on a platform in the calibration jig under the carriage, leveled, and lowered into the water where it could be rotated both horizontally and vertically. The pitot tube was submerged approximately three feet (0.91 m) below the water surface and adjusted to the required angle of inclination. The

holes of the pitot tube were connected to the Scanivalve system for pressure measurements. Air was blown through the pressure lines to the pitot tube as the carriage began to move. A brief bleed period preceded each pressure reading, which was taken when the carriage was traveling at a steady speed. Figure 9 shows a pitot tube during the air bleed cycle, and Figure 10 shows the same tube during the pressure measurement cycle.

The towing tank temperatures during the pre and post calibrations were 70 degrees and 67 degrees F (21.1 C and 19.4 C), respectively. Figure 11 shows the experimentally determined drag coefficients of typical spherically shaped bodies in different flow regimes. From this figure, it can be seen that flow speeds of 6 and 11 fps (1.83 and 3.35 m/s) correspond to a subcritical flow pattern, and those of 25 and 30 fps (7.62 and 9.14 m/s) correspond to a supercritical pattern. The supercritical pattern, with much less flow separation, is indicated by the sharp reduction in the drag coefficient.

As stated in the previous section, the differential pressure ratios were calculated on the Interdata computer and manually plotted onboard the carriage. Plotting the data served as a check to determine if the values, or experiment spots, appeared reasonable based upon the expected outcome from previous calibrations. The plots were once again checked and their values entered into program POLYFIT, which is a least squares curve fitting routine. POLYFIT, in turn, generated the final plots of the calibration curves and their coefficients. Appendix A describes how to use the calibration curves to obtain velocity component ratios.

The complete calibration of a tube consisted of runs at five degree intervals within a 60 degree arc, 30 degrees each side of zero, for

both planes. The original plan called for 38 tubes to be calibrated. Tubes numbered 1-35 were 5-hole pitot tubes, and those numbered 36, 37 and 38 were 13-hole pitot tubes. Due to time and scheduling constraints, only twenty-five and twenty-eight pitot tubes were calibrated for the pre and post calibrations, respectively. Table 2 lists those tubes which actually were calibrated. All tubes were calibrated at a speed of 20 fps (6.10 m/s). To study the effect of speed, measurements were also obtained at speeds of 6, 11, and 25 fps (1.83, 3.35 and 7.62 m/s) for tube 13 and at 6, 11, 25 and 30 fps (1.83, 3.35, 7.62 and 9.14 m/s) for tube 37. See page 11 for a discussion of speed effects.

Since seven 5-hole combinations can be derived from a single 13-hole tube, the number of data points for each 13-hole tube is significantly larger. Figure 3 presents the seven combinations of 5-hole tubes and gives a pictorial representation of the relationship of holes on the 13-hole tube. During the calibration, calculations were made for each of the seven combinations so that the redundancy of the data could be examined.

PRESENTATION AND DISCUSSION OF RESULTS

The results of the pre and post calibrations are the differential pressure ratio coefficients, presented in graphical form as a function of angle of inclination at four different speeds. The calibration curves consist of from 7 to 13 data points collected for each of the 25 5-hole pitot tubes in each of the two planes. Each data point on a curve consists of the value for the differential pressure ratio from which flow directions and magnitudes can be calculated for both the tangential and radial components. Appendix A presents the procedure for deriving velocity component ratios from pressure measurements.

In this study, the coefficients for each calibration were generated from the experimental data in the program POLYFIT. Appendix B explains the quantities which the coefficients represent. POLYFIT fairs a curve through the 7 to 13 given data points and computes 100 intermediate points. Curves from third and fourth degree polynomials were examined, and the one with the highest correlation coefficient to the given points was chosen as the calibration curve to be used for a particular tube, plane and speed. In each instance, the curve used gave an accurate fit.

Figures 12-58 present the pre calibrations of the 5-hole pitot tubes. Figures 22-27 show the results for tube 13 at speeds of 6, 11 and 20 fps (1.83, 3.35 and 6.10 m/s). Figures 59-114 present the post calibrations of the 5-hole pitot tubes, with Figures 73-80 showing the results for tube 13 run at 6, 11, 20 and 25 fps (1.83, 3.35, 6.10 and 7.62 m/s). Figures 115-126 present the pre calibrations of the 13-hole pitot tubes and Figures 127-134 present the post calibrations of the 13-hole pitot tubes. The data from Tube 37 for speeds others than 20 fps (6.10 m/s) will be presented in a future report.

The calibrations of Tube 9 in the horizontal/tangential plane, Figures 17 and 68, illustrate the greatest differences between the pre and post calibrations. At β = -10 deg, $(C - T_2)/V^2$ is equal to 0.0051 in the pre calibration but is 0.0056 in the post calibration. This difference would result in a five percent error in the prediction of the velocity, V. However, Tube 9 results were not consistent with the results of other calibrations in which the differences between pre and post calibration velocity predictions were on the order of one to two percent.

To compare the calibrations of various tubes, composite calibrations

were derived from each individual experiment. The composite data represent a statistical average over all tubes for a given experimental condition and are presented in this report in Figures 135-138. The statistical analysis of the composite data for the 5-hole pitot tube consists of the mean, maximum and minimum values, and tolerance intervals. In the composite plots, the curves have been faired through the mean values which are assumed to be representative of all tubes. Any differences which appear can be attributed to experimental error and/or imperfection in manufacture. The fairing process should average out experimental errors to give an unbiased estimate of the true value.

The population of this statistical analysis has as its elements the pressure readings for the 5-hole pitot tubes in the horizontal/tangential and vertical/radial planes for both the pre and post calibrations. The mean, minimum and maximum values and the tolerance intervals have been calculated for each angle from the samples obtained during the experiment and are presented in Tables 3-10 and Figures 135-138.

Attention is now directed to the accuracy of the calibrations, using the consistency of the data as the main criterion for evaluating the results. Any inconsistency in the data would indicate a tube irregularity due to improper manufacture or damage during the trial.

A 99 percent distribution-free tolerance region has been determined for this analysis. This tolerance interval is a generalization of the confidence interval corresponding to a band of values as opposed to a single value and gives an indication as to the interval in which a given percentage of the population should fall. The 99 percent tolerance interval means that there is 99 percent confidence that 99 percent of the distribution will lie between the indicated bounds.

Mathematically, this probability concentration of the sample population is expressed as follows:

$$P \{\int_R dF \geq .99\} = .99$$

Comparing the results of the pre and post calibrations in Figures 135 through 138, the agreement between corresponding data points in both planes, at least for the constant speed of 20 fps (6.10 m/s), can be readily seen. Almost all of the values fall within the bounds of the tolerance intervals. The exceptions are the minimum values corresponding to β angles of $\pm$25 deg and $\pm$30 deg of curves 1 and 3 in the pre calibration horizontal/tangential plane (Figure 135) which fall below the tolerance limit. Since this occurs only in this plane and at these angles, the abnormally low values should be attributable to an isolated tube which perhaps had a bad pre calibration.

Comparison of the mean values of the differential pressure ratio coefficients for the pre and post calibrations for each plane, as listed in Tables 3-10, reveals some differences. In general, the post calibration mean values are higher than the pre calibration values. In Table 4, the statistical summary for $(C - T_1)/V^2$ at β = 10 deg lists the pre calibration mean as 0.00517 and the post calibration mean as 0.00535. This difference would result in an error of less than two percent in the prediction of the velocity, V. For most of the mean values, the differences between pre and post calibration are even less, indicating an even smaller error.

Though the differences between the statistical averages of the pre and post calibration are small, the scatter of the data between different calibrations is large. This scatter is probably due to

manufacturing differences in the pitot tubes, though tank turbulence and experimental error do have an effect. The post calibration mean value of 0.00523 and maximum values of 0.00562 for $(C - R_2)/V^2$ at $\beta = -10$ deg are shown in Table 10. The difference in these two values would result in an error in the predicted velocity, V, of almost four percent. Though this example was selected as an extreme case, errors of two to three percent were not uncommon.

To determine the effect of towing speed on the calibrations, tube 13 was run at 6, 11, 20 and 25 fps (1.83, 3.35, 6.10 and 7.62 m/s) in both the pre and post calibrations. The results are presented in Figures 22 through 27 and in Figures 73 through 80. Composite results for the horizontal/tangential plane post calibration, which are typical, are presented in Figure 139. Significant differences are evident, particularly at the lowest speed. The value for $(C - T_2)/V^2$ at $\beta = -10$ deg at 6 fps is 0.0049 and at 20 fps is 0.0054. This difference would result in an error in the predicted velocity of about five percent. However, at the other speeds, the differences are much less significant.

The speed of 20 fps (6.10 m/s) was selected for the calibrations based on the physical limitations of the calibration equipment such as excessive water spray and rake vibrations. Referring to Figure 11, the speed of 20 fps (6.10 m/s) is seen to be in the transcritical flow pattern regime and the speed of 25 fps (7.62 m/s) is seen to be in the supercritical flow regime. However, since the data presented in Figure 139 show that the calibrations at 20 and 25 fps (6.10 and 7.62 m/s) are practically identical, any transcritical effects on the calibrations are assumed to be negligible. Therefore, the complete set of calibrations at 20 fps (6.10 m/s) is considered valid for the analysis of full-scale data.

CONCLUSIONS

As a result of this calibration analysis, the following conclusions can be reached:

(1) The differences between the pre and post calibrations for a given tube were generally small. The difference in the predicted velocity using the pre and post calibrations at $\beta \approx 10$ deg was typically one to two percent.

(2) The calibrations of individual pitot tubes contained significant scatter about the mean values obtained by averaging the results of all tubes. The difference in the predicted velocity using the mean and actual calibrations was typically two to three percent.

(3) The differences between the mean values over all tubes of the pre and post calibrations were small, indicating the absence of a bias between the pre and post calibrations.

(4) Based on conclusions (1), (2) and (3) above, individual pre and post calibrations for each tube will give more accurate predictions of velocity component ratios.

(5) At speeds of 20 fps (6.10 m/s) and above, the calibrations were relatively insensitive to speed change. However, at the lower speeds of 11 fps (3.35 m/s) and less, the calibrations were highly speed (or Reynolds number) dependent. Therefore, the validity of the calibrations listed in this report has only been demonstrated in the speed range of 20 to 30 fps (6.10 to 9.14 m/s), though the calibrations should also be accurate at higher speeds.

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2. Janes, C.E., "Instruments and Methods for Measuring the Flow of Water Around Ships and Ship Models," David W. Taylor Model Basin Report No. 487 (March 1948).

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TABLES

TABLE 1

REYNOLDS NUMBERS* FOR THE TEMPERATURE AND SPEED RANGE OF THE CALIBRATIONS

SPEED FT/SEC	PRE CAL $Rn \times 10^{-5}$ $T = 70^{o}F$:FW	POST CAL $Rn \times 10^{-5}$ $T = 67^{o}$ F:FW
6	1.125	1.081
11	2.063	1.982
15	2.813	2.703
20	3.751	3.604
25	4.689	4.505
30	5.626	5.406

$Rn = 5.212 \times 10^{5}$: Full Scale Trial Conditions
Sea Water $T = 82^{o}F$ ($27.8^{o}C$)

* The diameter of the spherical head of the pitot tube is the characteristic length used.

TABLE 2

CALIBRATED PITOT TUBES

PRE CALIBRATION 5-Hole Tube Number	POST CALIBRATION 5-Hole Tube Number
4	3
6	4
9	5
11	6
12	9
13	11
15	12
17	13
18	15
20	16
21	17
22	20
23	21
24	22
26	23
27	24
28	26
29	27
30	28
31	29
32	30
33	31
	32
	33
	34

13-Hole Tube Number	13-Hole Tube Number
36	37
37	38
38	

Table 3 STATISTICAL CALIBRATION SUMMARY FOR $\frac{T_2 - T_1}{2C - T_2 - T_1}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	-.008	.000	.008	.018	.024	.005
5	.295	.311	.327	.346	.358	.010
10	.629	.640	.661	.676	.693	.010
15	1.001	1.019	1.038	1.057	1.075	.011
20	1.389	1.390	1.487	1.530	1.585	.030
25	1.820	1.763	2.086	2.189	2.353	.081
30	2.482	2.418	3.002	3.220	3.521	.158
			Post Calibration			
0	-.017	.002	.009	.019	.036	.008
5	.276	.287	.329	.357	.382	.016
10	.619	.629	.669	.686	.719	.015
15	.982	1.006	1.044	1.082	1.105	.019
20	1.302	1.443	1.488	1.526	1.673	.032
25	1.805	2.024	2.105	2.159	2.405	.052

Table 4 STATISTICAL CALIBRATION SUMMARY FOR $\frac{C - T_1}{V^2}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	.00301	.0032	.00328	.0035	.00356	.00008
5	.00399	.0040	.00425	.0044	.00451	.00008
10	.00486	.0050	.00517	.0053	.00547	.00009
15	.00557	.0058	.00589	.0061	.00621	.00010
20	.00611	.0063	.00643	.0066	.00674	.00010
25	.00639	.0066	.00675	.0069	.00710	.00011
30	.00660	.0068	.00697	.0071	.00735	.00011
			Post Calibration			
0	.00303	.00314	.00330	.00349	.00357	.00008
5	.00399	.00413	.00435	.00454	.00471	.00011
10	.00492	.00514	.00535	.00561	.00578	.00013
15	.00566	.00589	.00608	.00634	.00649	.00013
20	.00634	.00653	.00660	.00664	.00685	.00004
25	.00631	.00685	.00694	.00712	.00756	.00011

Table 5 STATISTICAL CALIBRATION SUMMARY FOR $\frac{T_1 - T_2}{C - T_1 - T_2}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	-.008	.000	.008	.018	.024	.005
-5	.296	.307	.327	.345	.359	.010
-10	.635	.651	.669	.692	.704	.010
-15	1.007	1.021	1.042	1.060	1.077	.011
-20	1.413	1.426	1.494	1.531	1.576	.025
-25	1.825	1.758	2.090	2.157	2.355	.081
-30	2.439	2.310	3.001	3.215	3.563	.171
			Post Calibration			
0	-.017	.003	.009	.040	.035	.008
-5	.289	.306	.326	.363	.363	.011
-10	.635	.652	.669	.693	.704	.011
-15	.987	1.011	1.038	1.076	1.090	.016
-20	1.315	1.432	1.469	1.506	1.623	.026
-25	1.694	1.995	2.092	2.175	2.491	.068

Table 6 STATISTICAL CALIBRATION SUMMARY FOR $\frac{C - T_2}{V^2}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	.00301	.0032	.00328	.0034	.00356	.00008
-5	.00413	.0042	.00429	.0045	.00445	.00005
-10	.00483	.0051	.00521	.0055	.00559	.00012
-15	.00552	.0058	.00589	.0061	.00626	.00011
-20	.00607	.0063	.00643	.0067	.00680	.00011
-25	.00639	.0066	.00676	.0070	.00713	.00011
-30	.00657	.0068	.00699	.0074	.00741	.00013
			Post Calibration			
0	.00302	.00312	.00330	.00349	.00358	.00009
-5	.00408	.00425	.00439	.00468	.00469	.00009
-10	.00497	.00522	.00536	.00573	.00576	.00012
-15	.00565	.00592	.00607	.00651	.00650	.00013
-20	.00547	.00644	.00670	.00702	.00794	.00021
-25	.00561	.00682	.00701	.00741	.00841	.00024

Table 7 STATISTICAL CALIBRATION SUMMARY FOR $\frac{R_2 - R_1}{2C - R_2 - R_1}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	-.020	.004	.014	.039	.048	.010
5	.283	.296	.336	.369	.390	.016
10	.621	.638	.677	.710	.733	.017
15	.953	1.030	1.063	1.192	1.173	.034
20	1.437	1.454	1.511	1.560	1.584	.022
25	1.986	2.067	2.115	2.193	2.244	.039
30	2.701	2.811	3.002	3.151	3.302	.091
			Post Calibration			
0	-.016	.004	.025	.059	.066	.013
5	.314	.329	.350	.388	.387	.011
10	.644	.656	.696	.730	.748	.016
15	1.003	1.039	1.063	1.114	1.122	.018
20	1.284	1.460	1.523	1.571	1.762	.041
25	1.709	2.047	2.118	2.216	2.527	.070

Table 8 STATISTICAL CALIBRATION SUMMARY FOR $\frac{C - R_1}{V^2}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	.00296	.0031	.00326	.0034	.00356	.00009
5	.00394	.0041	.00427	.0045	.00461	.00010
10	.00489	.0051	.00519	.0054	.00549	.00009
15	.00550	.0057	.00591	.0062	.00631	.00012
20	.00610	.0063	.00644	.0067	.00679	.00011
25	.00641	.0066	.00679	.0071	.00717	.00012
30	.00665	.0069	.00705	.0073	.00744	.00012
			Post Calibration			
0	.00311	.00326	.00351	.00357	.00367	.00062
5	.00409	.00428	.00441	.00461	.00474	.00010
10	.00499	.00513	.00536	.00557	.00574	.00012
15	.00550	.00595	.00615	.00629	.00680	.00020
20	.00600	.00649	.00669	.00679	.00739	.00012
25	.00670	.00700	.00710	.00717	.00751	.00007

Table 9 STATISTICAL CALIBRATION SUMMARY FOR $\frac{R_1 - R_2}{2C - R_1 - R_2}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	-.020	.004	.014	.039	.048	.010
-5	.263	.282	.315	.352	.367	.016
-10	.611	.627	.654	.674	.698	.013
-15	.960	.991	1.027	1.064	1.093	.020
-20	1.404	1.438	1.480	1.518	1.555	.023
-25	1.930	2.017	2.100	2.189	2.270	.052
-30	2.509	2.751	3.058	3.325	3.608	.166
			Post Calibration			
0	-.012	.004	.025	.059	.063	.012
-5	.267	.277	.308	.328	.348	.013
-10	.580	.604	.648	.689	.716	.021
-15	.956	.989	1.025	1.058	1.093	.021
-20	1.247	1.412	1.463	1.498	1.678	.037
-25	1.769	2.007	2.096	2.161	2.423	.056

Table 10 STATISTICAL CALIBRATION SUMMARY FOR $\frac{C - R_2}{V^2}$

Flow Angle	Lower Tolerance Limit	Minimum	Mean	Maximum	Upper Tolerance Limit	Standard Deviation
			Pre Calibration			
0	.00296	.0031	.00326	.0034	.00356	.00009
-5	.00380	.0040	.00422	.0045	.00463	.00013
-10	.00468	.0049	.00513	.0054	.00559	.00014
-15	.00506	.0057	.00581	.0061	.00655	.00023
-20	.00584	.0062	.00636	.0067	.00687	.00016
-25	.00603	.0064	.00666	.0071	.00730	.00019
-30	.00609	.0065	.00688	.0075	.00766	.00024
			Post Calibration			
0	.00305	.00319	.00338	.00357	.00371	.00010
-5	.00400	.00417	.00428	.00451	.00456	.00009
-10	.00483	.00504	.00523	.00562	.00563	.00013
-15	.00553	.00582	.00596	.00663	.00639	.00013
-20	.00584	.00631	.00645	.00657	.00705	.00010
-25	.00615	.00663	.00678	.00693	.00740	.00011

FIGURES

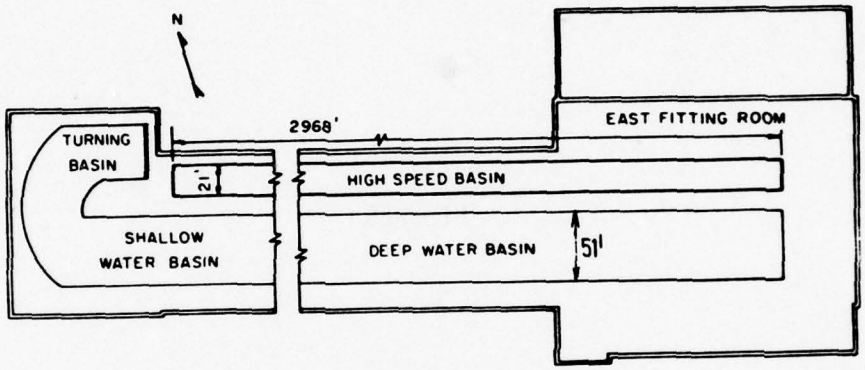


Figure 1 - Outline Plan of Deep Water and High Speed Basins

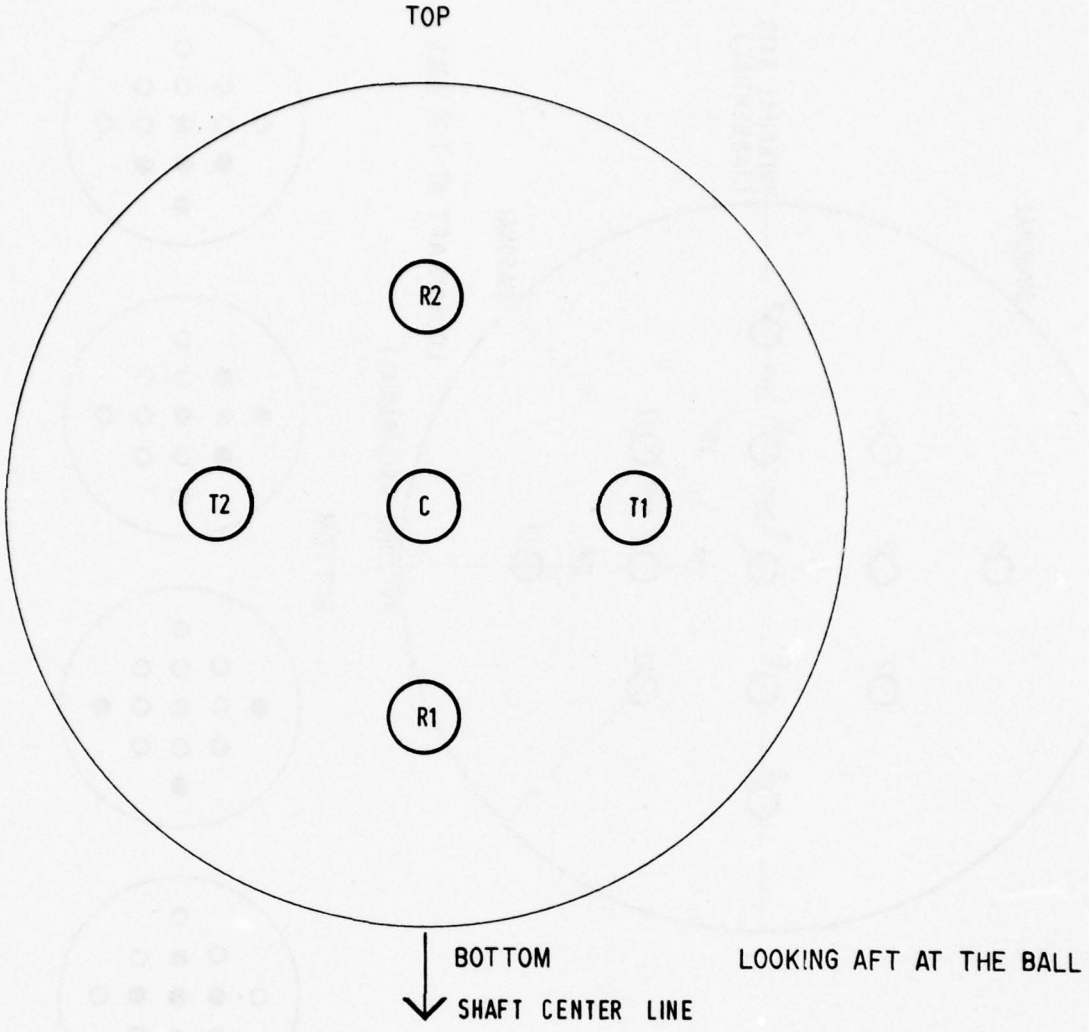


FIGURE 2 — SCHEMATIC OF 5-HOLE PITOT TUBE

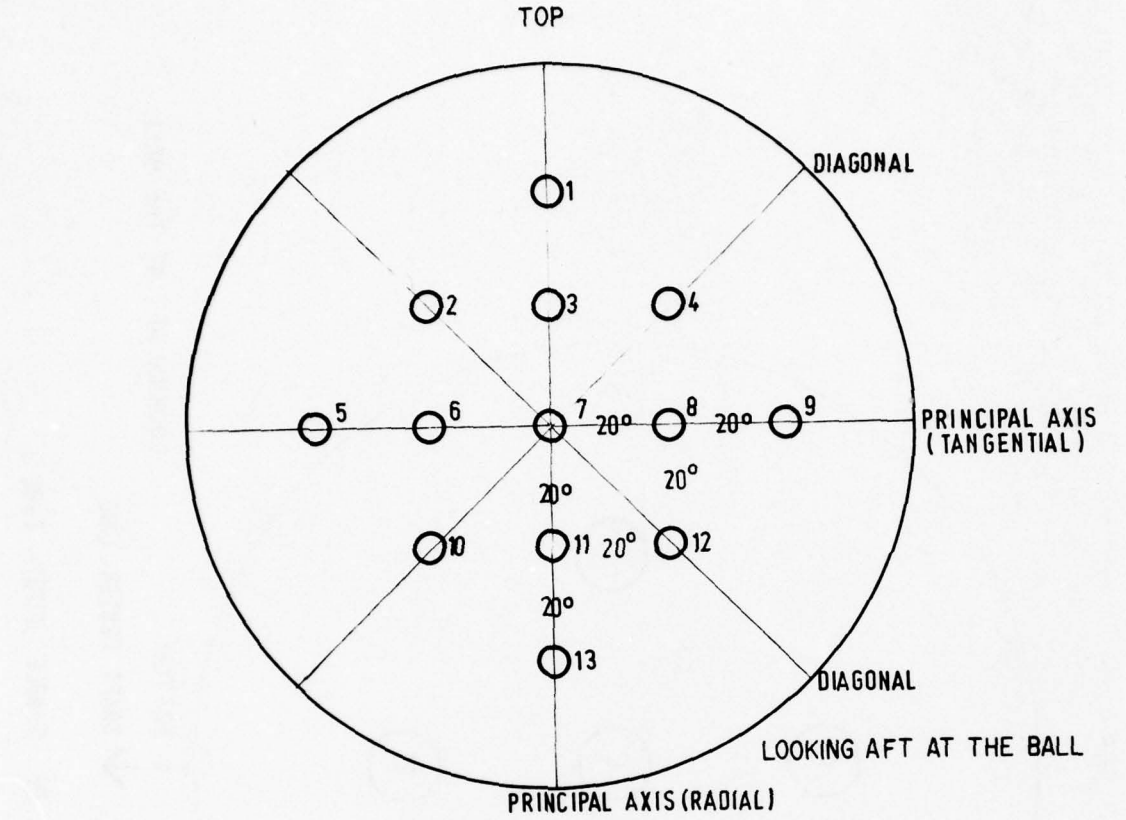


FIGURE 3 — SCHEMATIC OF 13-HOLE PITOT TUBE

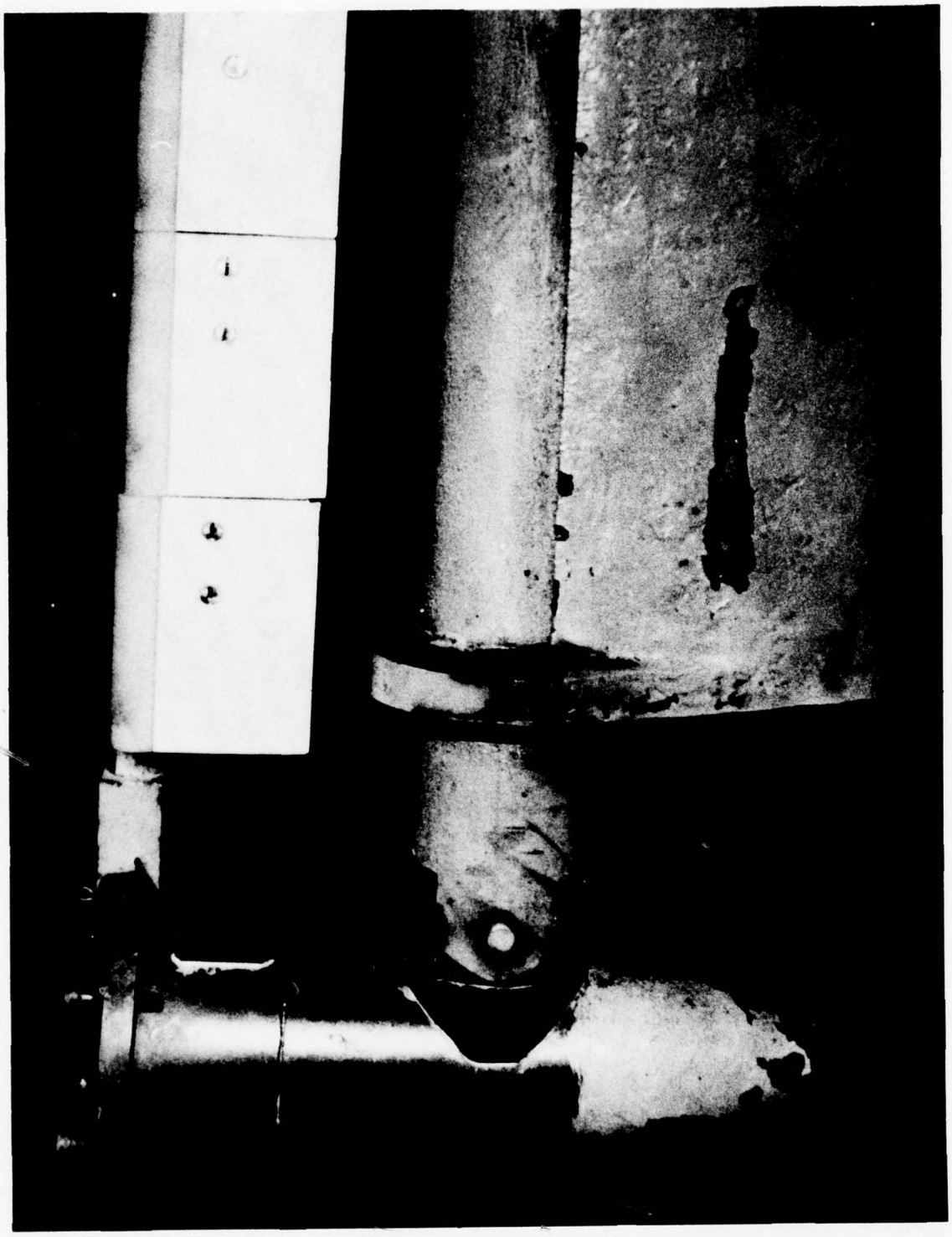


Figure 4 - Instrument Housing of Calibration Rake

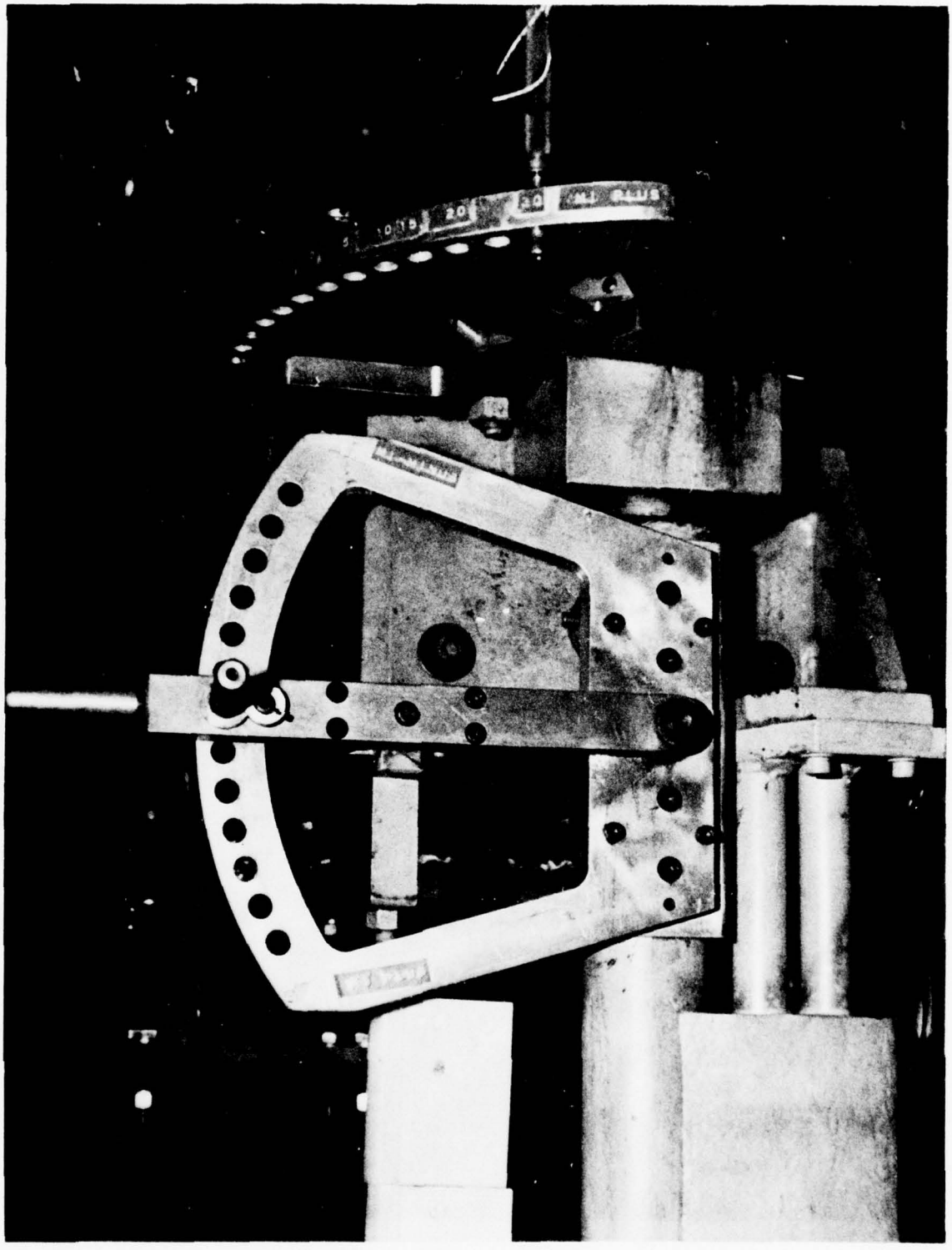


Figure 5 - Calibration Rake Showing Horizontal and Vertical Angular Quadrants

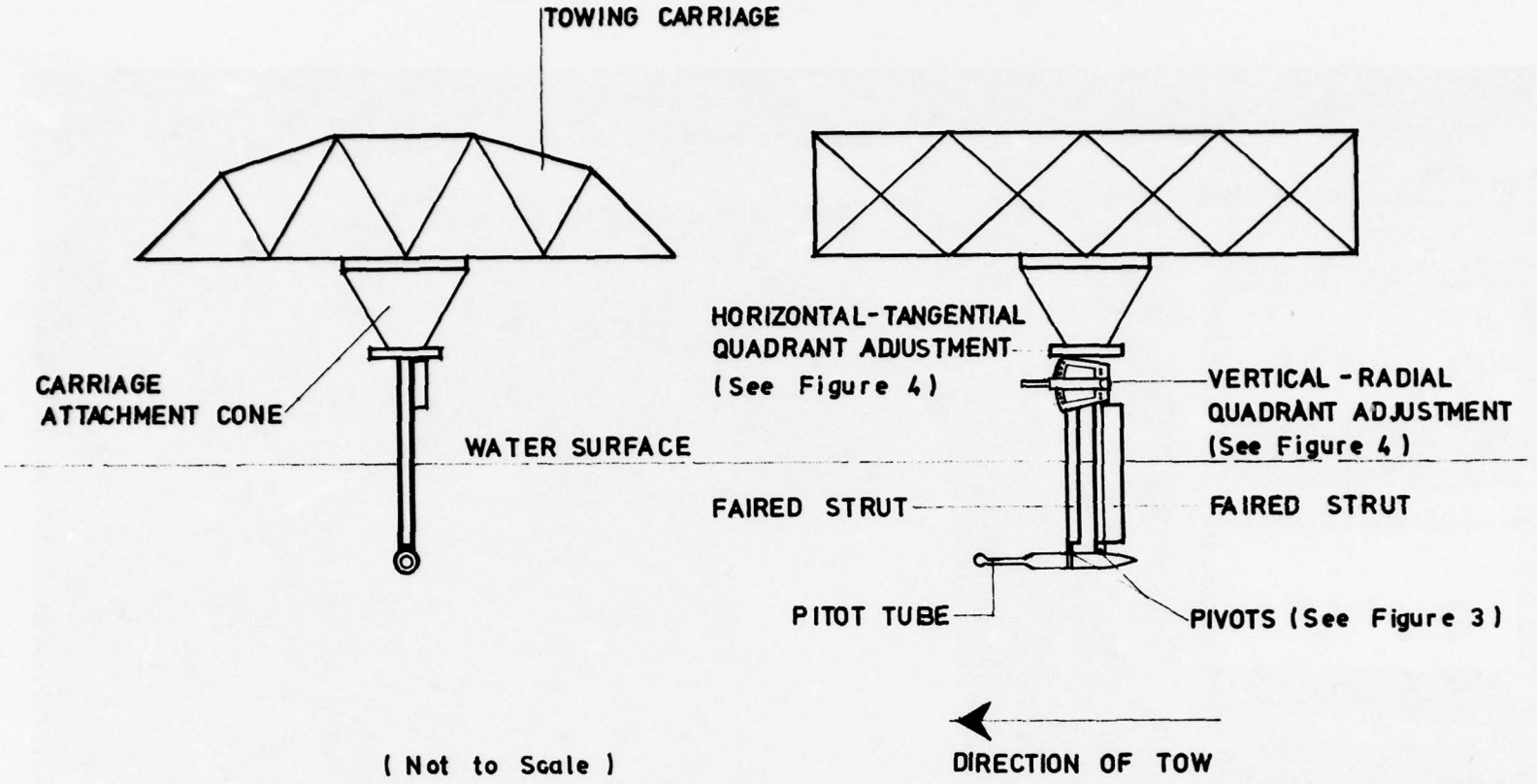


FIGURE 6 - SCHEMATIC OF CARRIAGE / CONE / RAKE ASSEMBLY

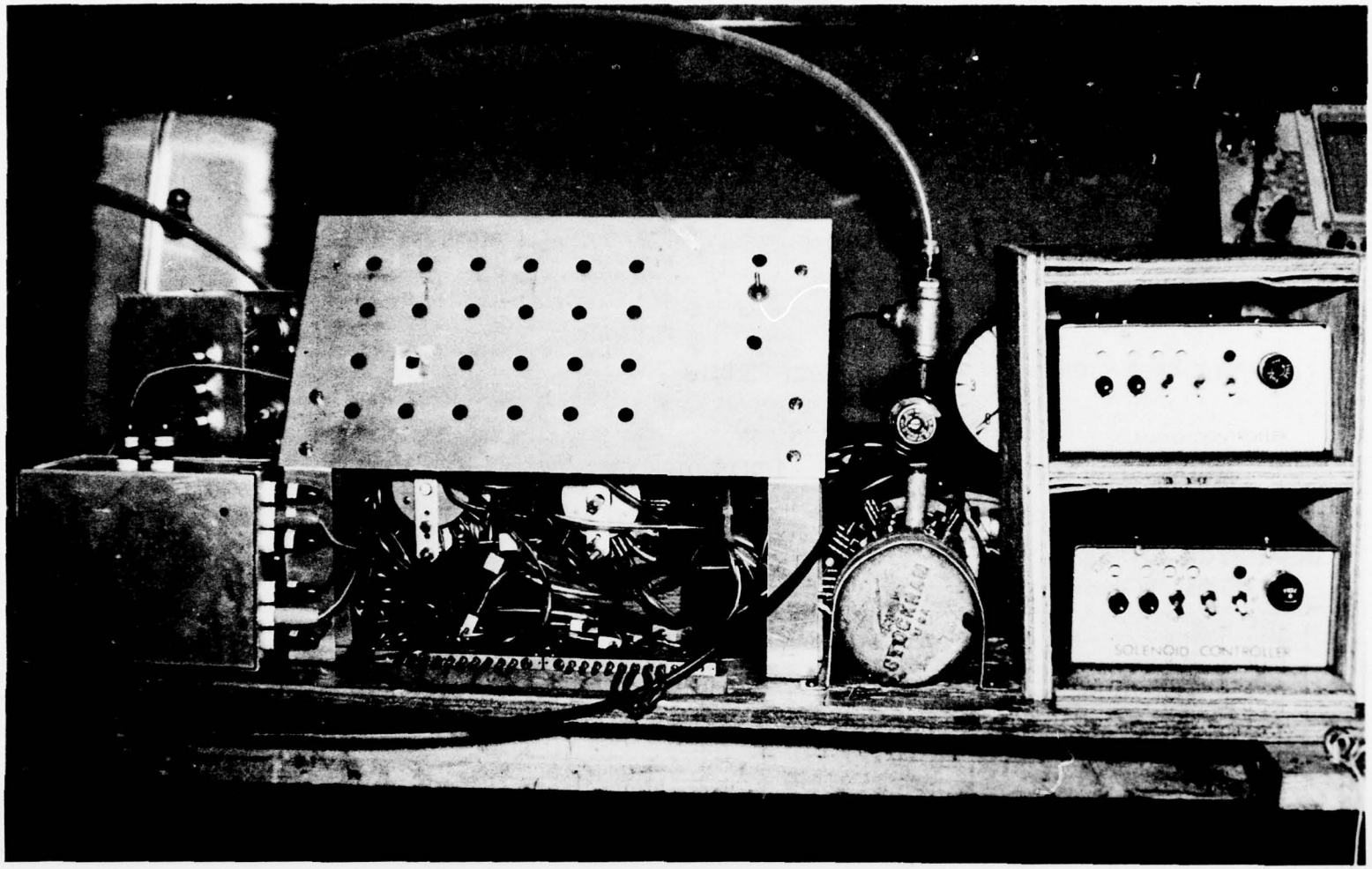


Figure 7 - Scanivalve Pressure Control and Measurement System

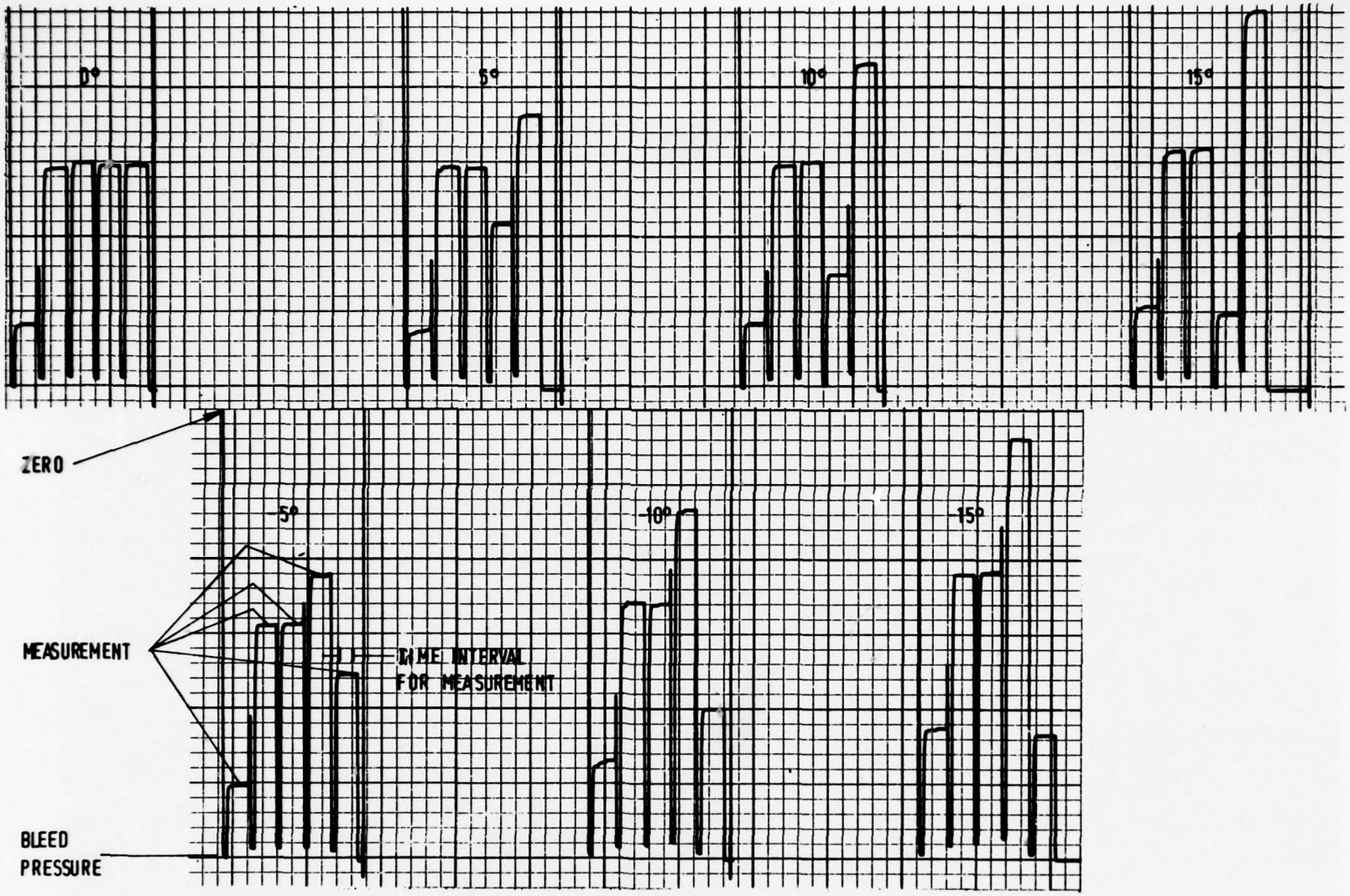
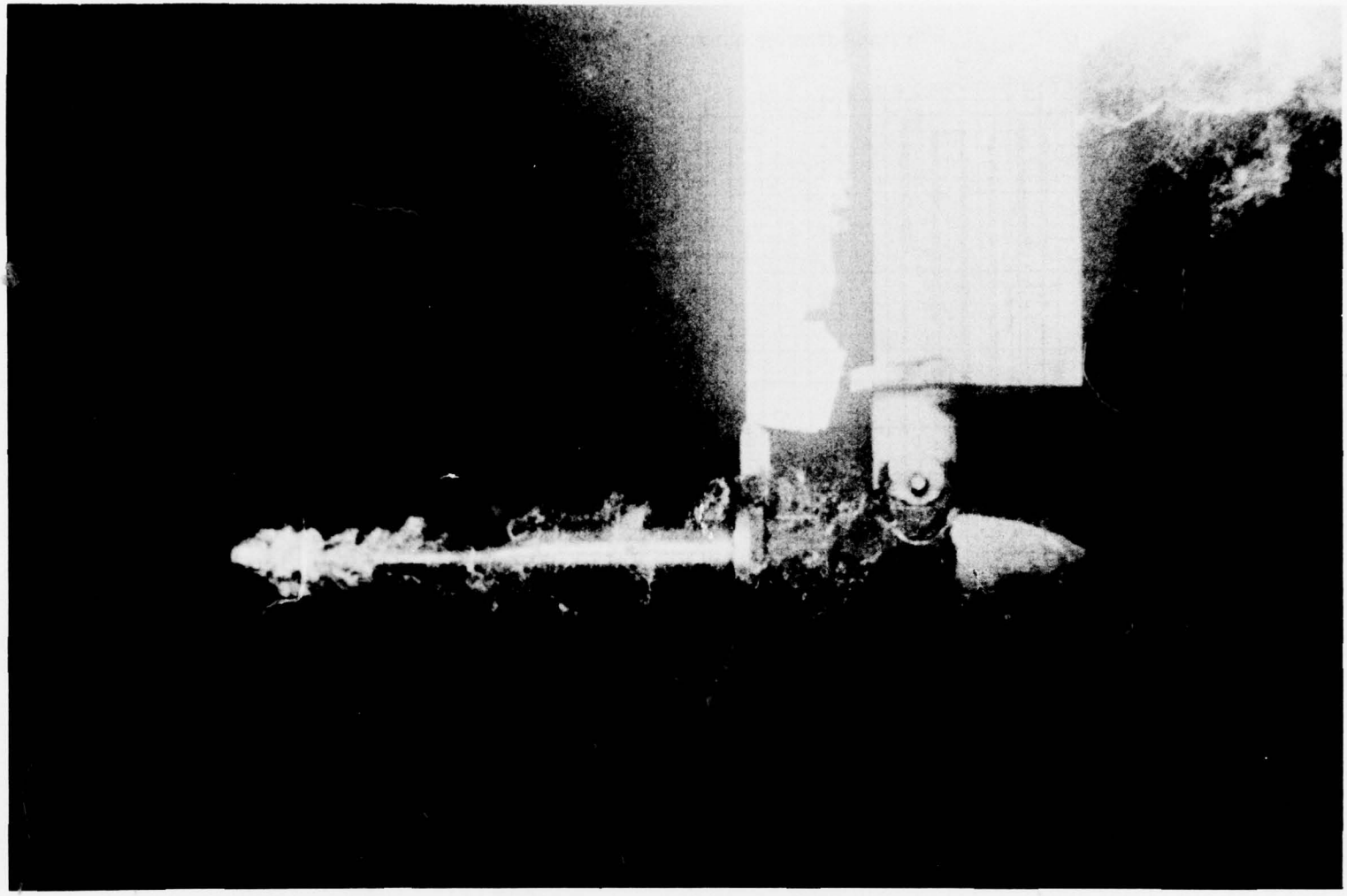
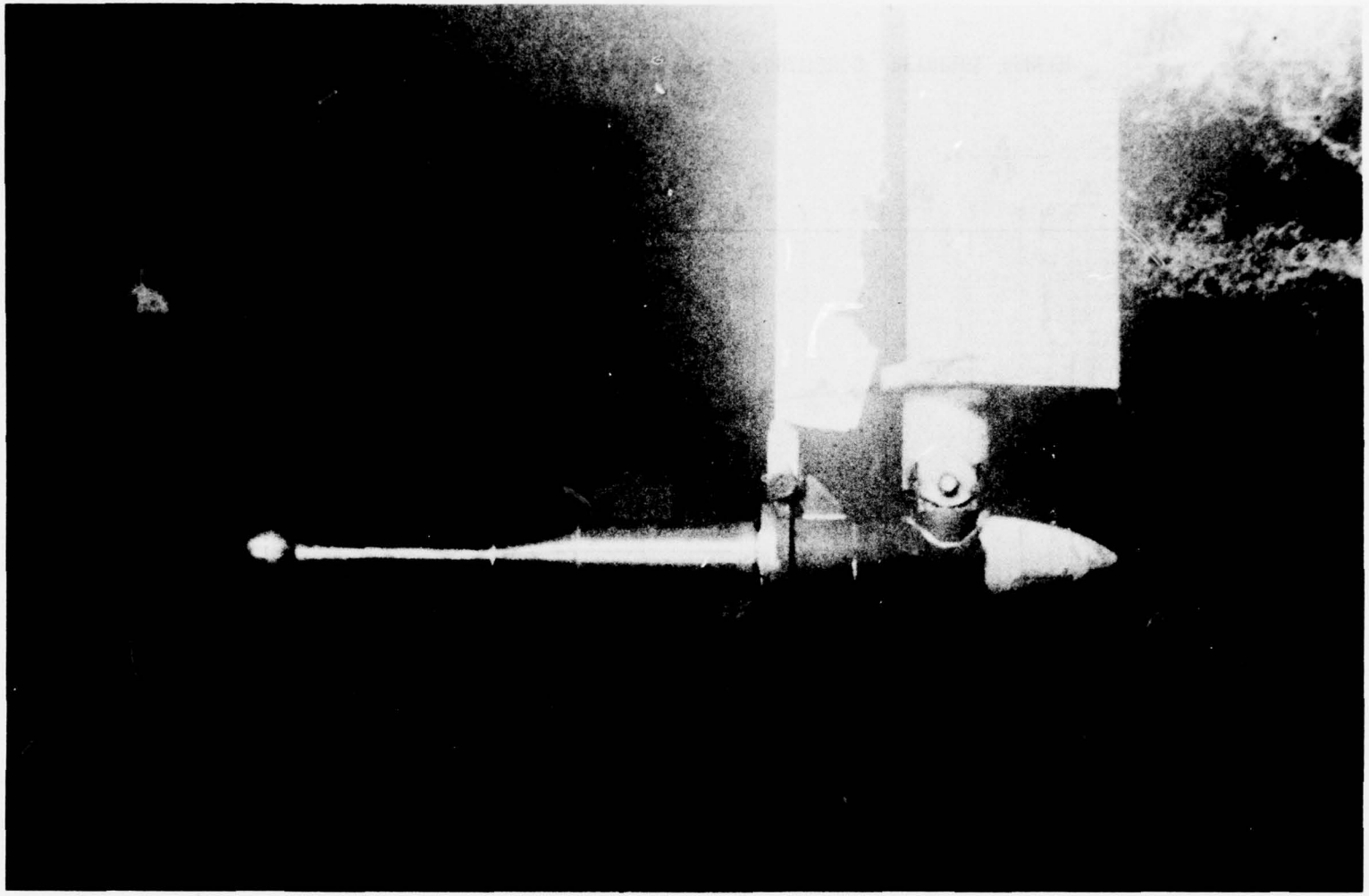


Figure 8 - Strip Chart Record of Pressure Measurements from a 5-Hole Pitot Tube



PSD 34744-

Figure 9 - Pitot Tube During Air Bleed Cycle



PSD 34744-

Figure 10 - Pitot Tube During Measuring Cycle

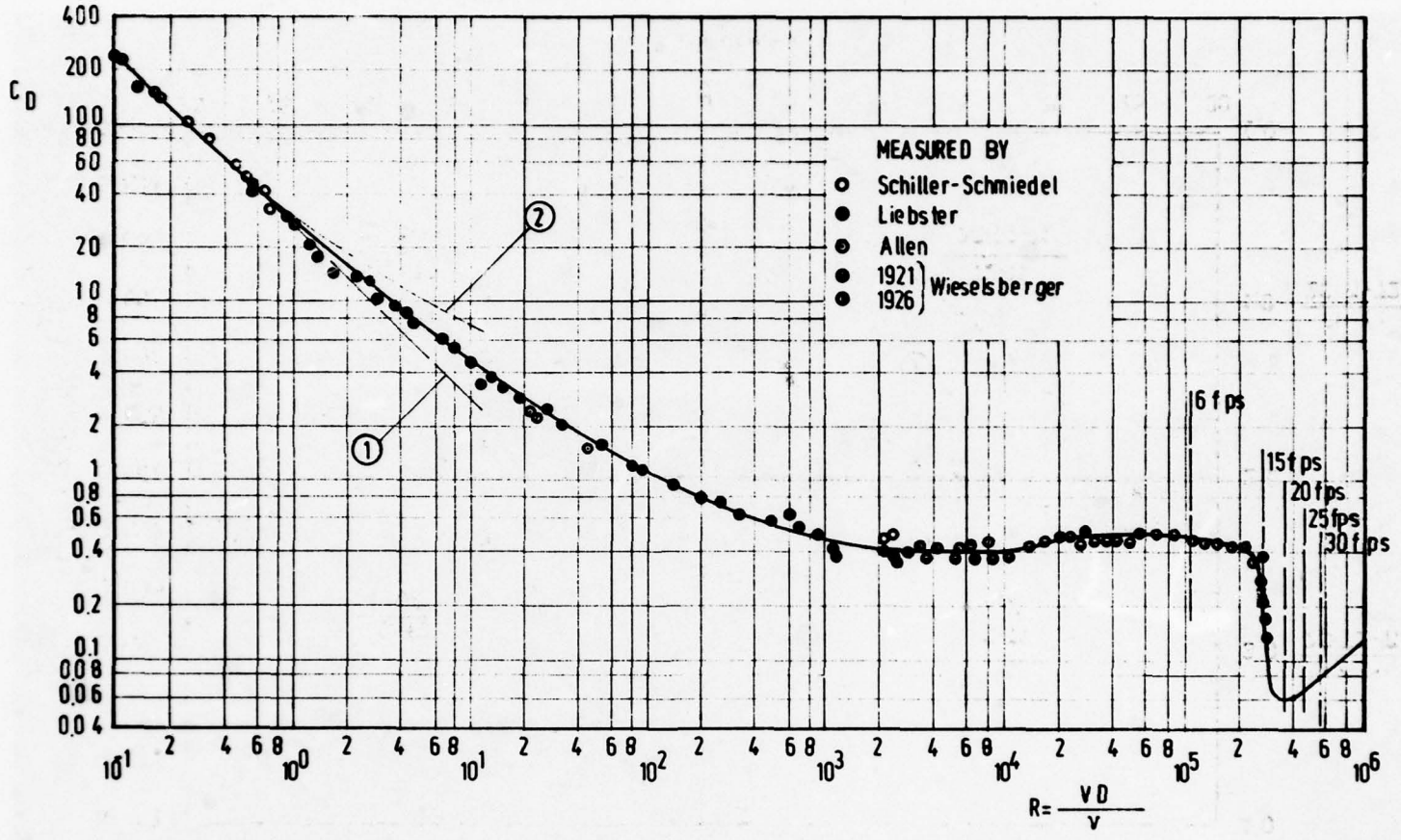


FIGURE 11-DRAG COEFFICIENT FOR SPHERES AS A FUNCTION OF REYNOLDS NUMBER *

* FROM REFERENCE 3

④	③	②	①
0.3306210 E-02	0.3857422E-01	0.3293991E-02	-0.7885742 E-01
-0.1896024 E-03	-0.1487500 E+02	0.1845956 E-03	0.1567578 E+02
0.1806766 E-05	-0.9062500E+00	0.1117587 E-05	0.4687500 E-01
0.2640299E-06	0.1675781 E+01	-0.1878943E-06	-0.1464844 E+01
0.4423782 E-08	-0.2770996E+00	0.2735760E-08	0.2590332 E+00

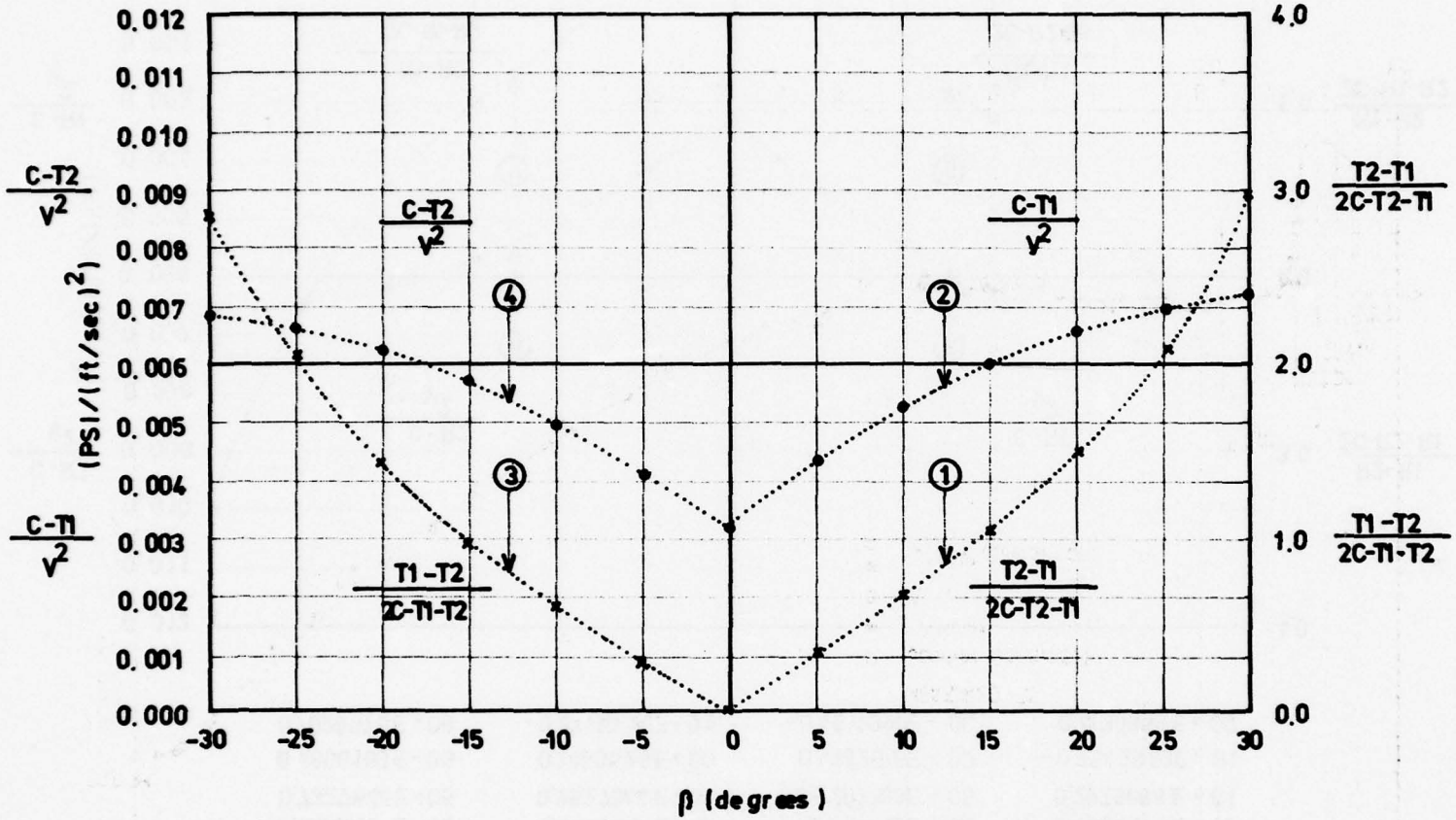


Figure 12 -Pre Calibration of Tube 4 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3295362 E-02	-0.1684570E-01	0.3302991E-02	-0.7641602E-01
-0.1384616 E-03	-0.1748828 E+02	0.2619028E-03	0.1334375E+02
0.7327646E-05	0.2527344E+01	-0.5297363E-05	0.2929688E+01
0.4866160E-06	0.2890625E+00	0.4982576E-07	-0.2542969E+01
0.7028575E-08	-0.8715820E+01	-0.4511094E-09	0.4130859E+00

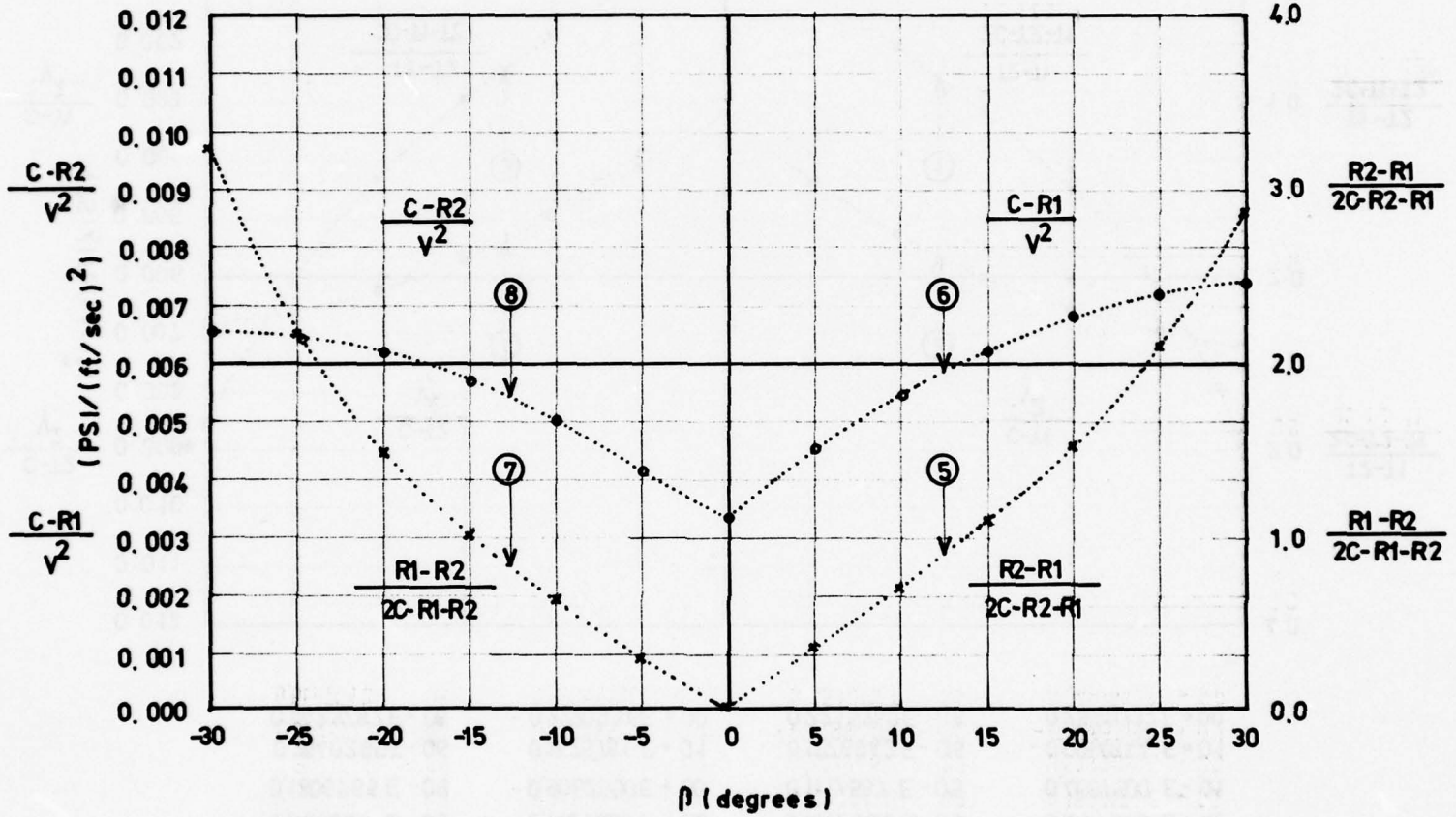


Figure 13 -Pre Calibration of Tube 4 in Vertical - Radial Plane

④	③	②	①
0.3201127E - 02	0.2954102E - 01	0.3202498E - 02	-0.4125977E - 01
-0.1867414E - 03	-0.1488672E + 02	0.1912713E - 03	0.1503125E + 02
0.3956258E - 05	-0.1144531E + 01	0.2719462E - 05	0.9179688E + 00
0.3976747E - 06	0.1910156E + 01	-0.3299210E - 06	-0.1886719E + 01
0.6592018E - 08	-0.3305664E + 00	0.5515176E - 08	0.3410645E + 00

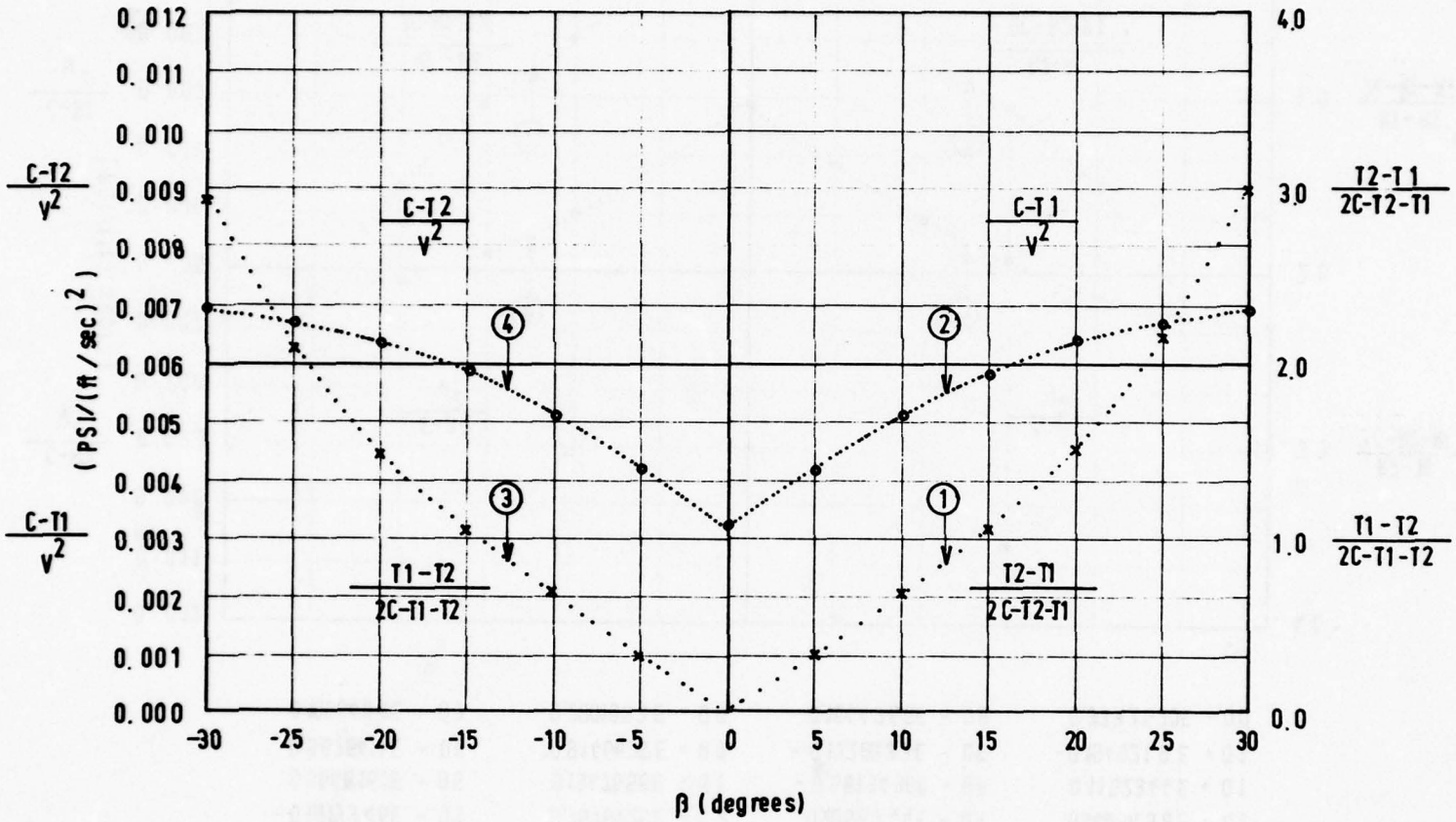


Figure 14 - Pre Calibration of Tube 6 in Horizontal - Tangential Plane

⑧	⑦	⑥	⑤
0.3101587E - 02	0.1650391E + 00	0.3199875E - 02	-0.1740723E + 00
-0.1817346E - 03	-0.1678125E + 02	0.2058744E - 03	0.1498438E + 02
0.5666167E - 05	0.1347656E + 01	-0.5513430E - 06	0.1152344E + 01
0.5676411E - 06	0.9140625E + 00	-0.1220033E - 06	-0.1949219E + 01
0.1056469E - 07	-0.2001953E + 00	0.1644366E - 08	0.3332520E + 00

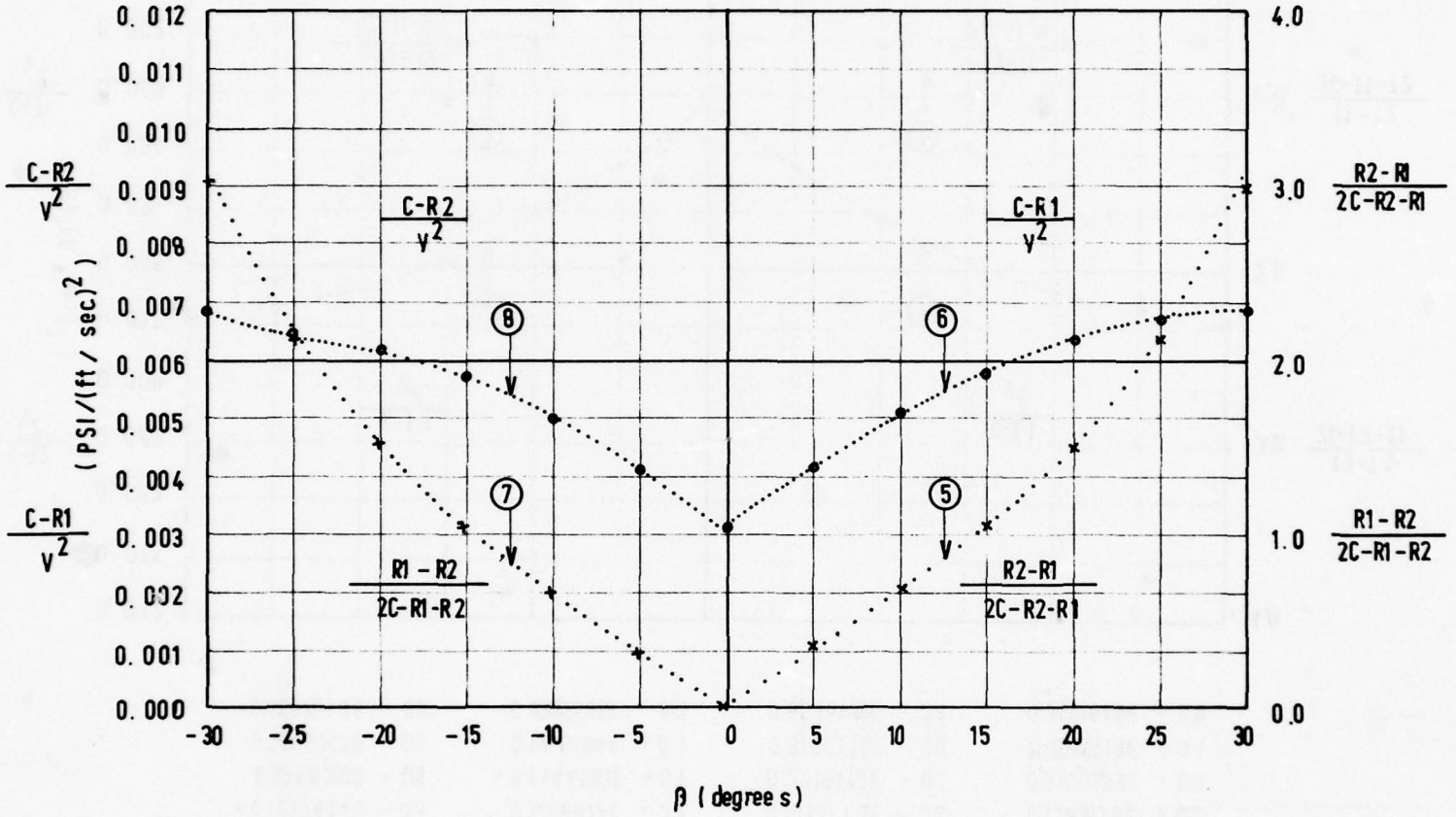


Figure 15 - Pre Calibration of Tube 6 in Vertical-Radial Plane

④	③	②	①
0.3305137E-02	0.5151367E-01	0.3294408E-02	-0.1579590E+00
-0.2087355E-03	-0.1623828E+02	0.2138615E-03	0.1580078E+02
-0.2704561E-05	0.3437500E+00	-0.1121312E-05	-0.2031250E+00
-0.7916242E-08	0.1230469E+01	-0.1527369E-06	-0.1261719E+07
-0.5238689E-09	-0.2187500E+00	0.2852175E-08	0.2231445E+00

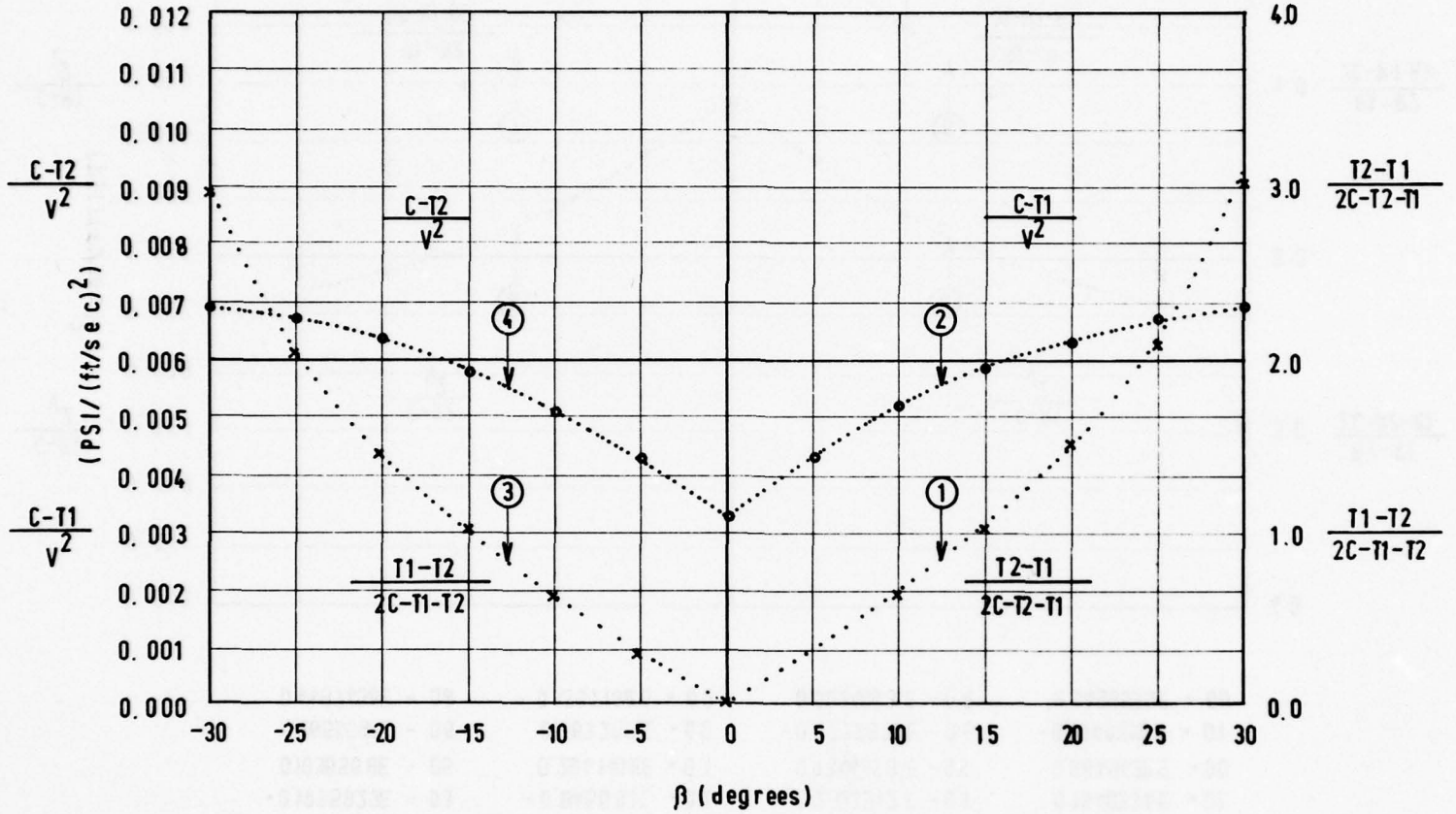


Figure 16 - Pre Calibration of Tube 9 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3292084E - 02	0.2827148E +00	0.3298759E - 02	-0.2614746E +00
-0.1835823E - 03	- 0.1846094E +02	0.2003312E - 03	0.1540234E +02
0.1836568E - 05	0.2941406E +01	0.1344830E - 05	0.9648438E +00
0.2656598E - 06	0.3632813E +00	-0.2777670E - 06	- 0.1949219E +01
0.4467438E - 08	- 0.1367188E +00	0.5034963E - 08	0.3498535E +00

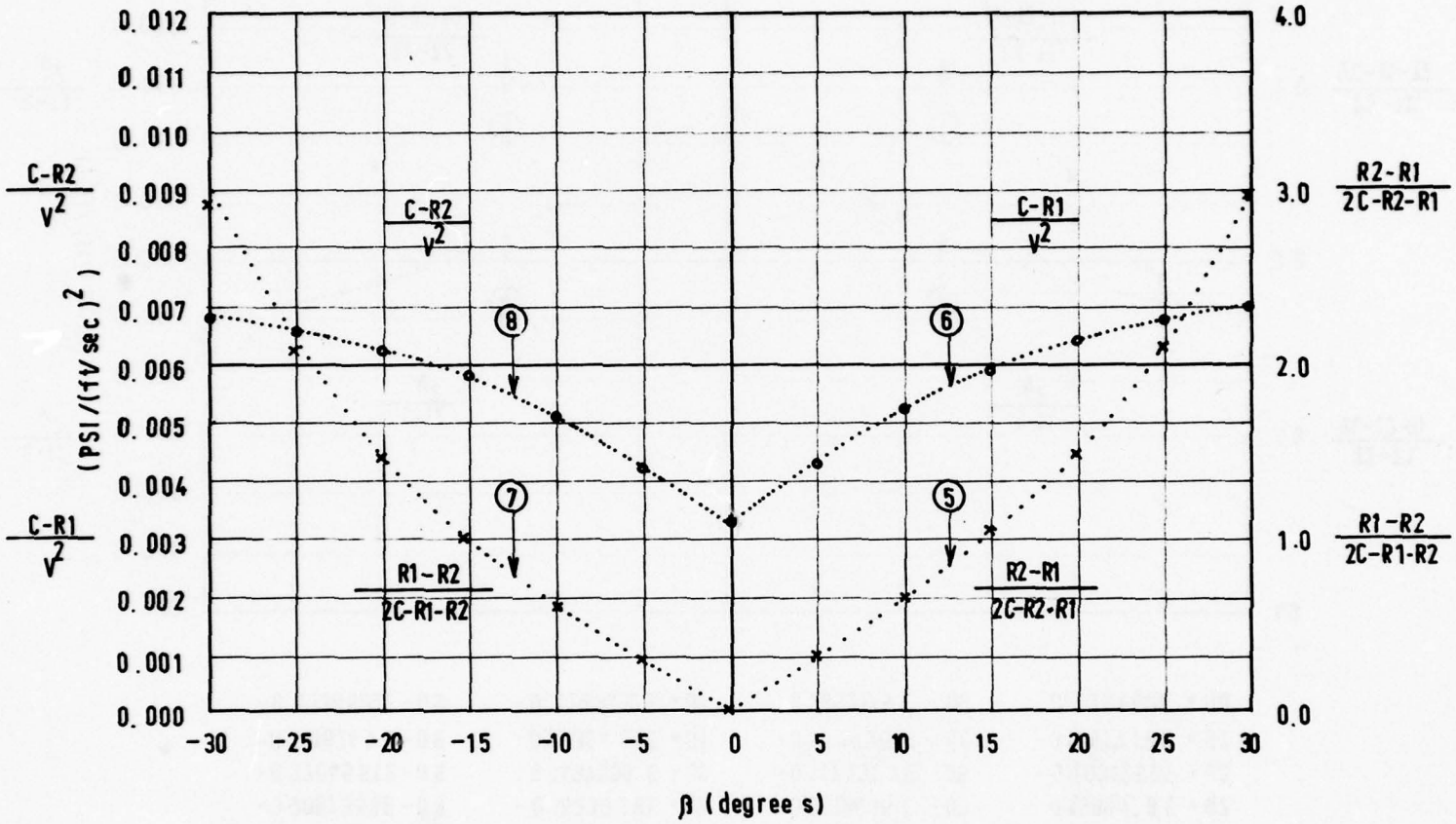


Figure 17 - Pre Calibration of Tube 9 in Vertical - Radial Plane

④	③	②	①
0.3190279E-02	0.2019043E+00	0.3298402E-02	-0.1862793E+00
-0.2268553E-03	-0.1703516E+02	0.2015233E-03	0.1519551E+02
-0.3222376E-05	0.2074219E+01	0.6854534E-06	0.1156250E+01
0.4656613E-08	0.2343750E+00	-0.1834705E-06	-0.1945313E+01
0.5820766E-10	-0.5102539E-01	0.2677552E-08	0.3359375E+00

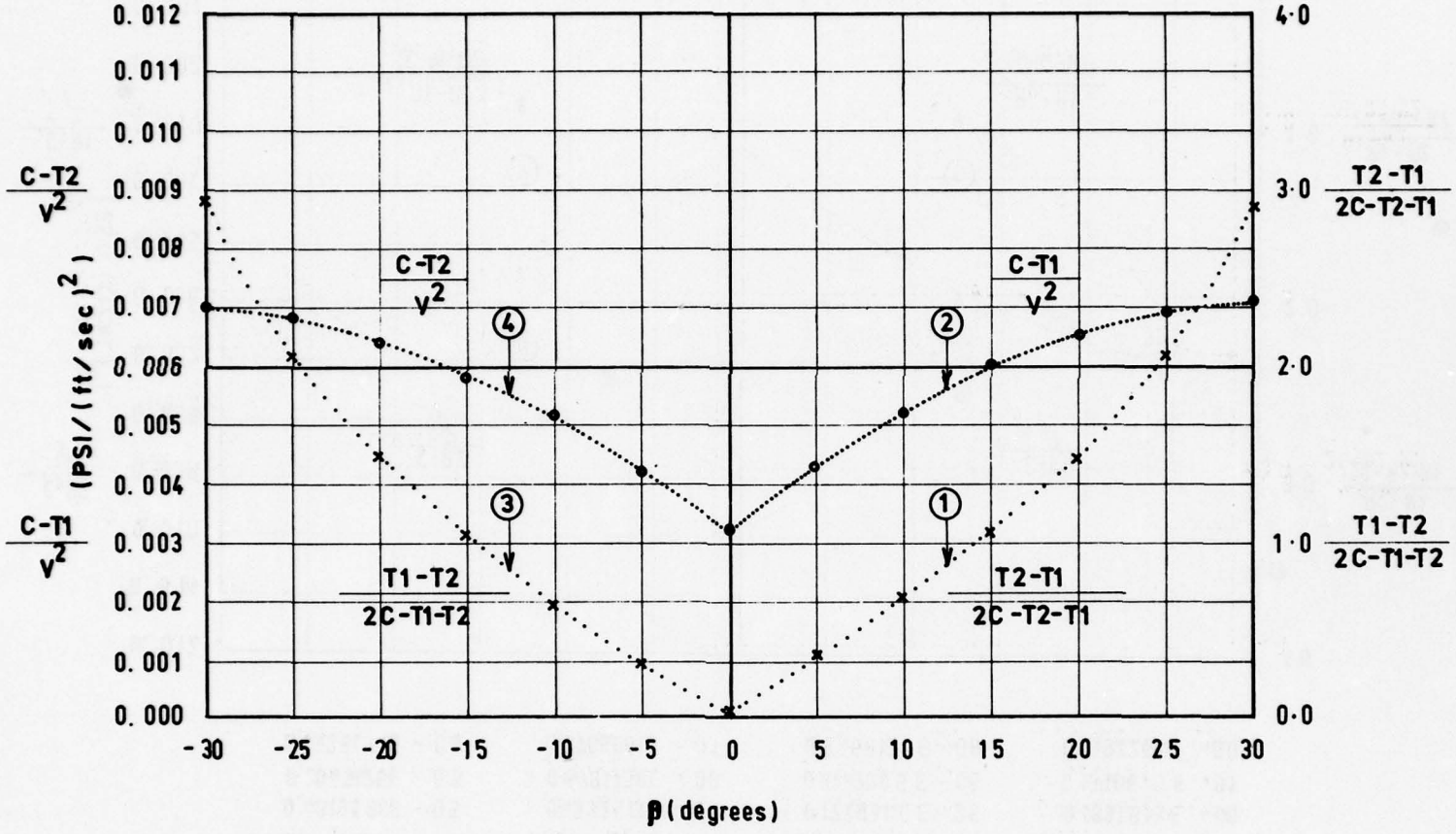


Figure 18 - Pre Calibration of Tube 11 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3291786E - 02	06088867E + 00	0.3307283E - 02	-0.5893555 E +00.
-0.1543164 E - 03	-0.1979688E + 02	0.2149940 E - 03	0.1525391 E +02
0.4019588E - 05	0.4632813E +01	0.1229346 E - 06	0.4882813 E +00
0.3045425E - 06	-0.5781250E +00	-0.2137385 E - 06	-0.1390625 E +01
0.4336471E - 08	0.2709961E - 01	0.3958121 E - 08	0.2197266 E +00

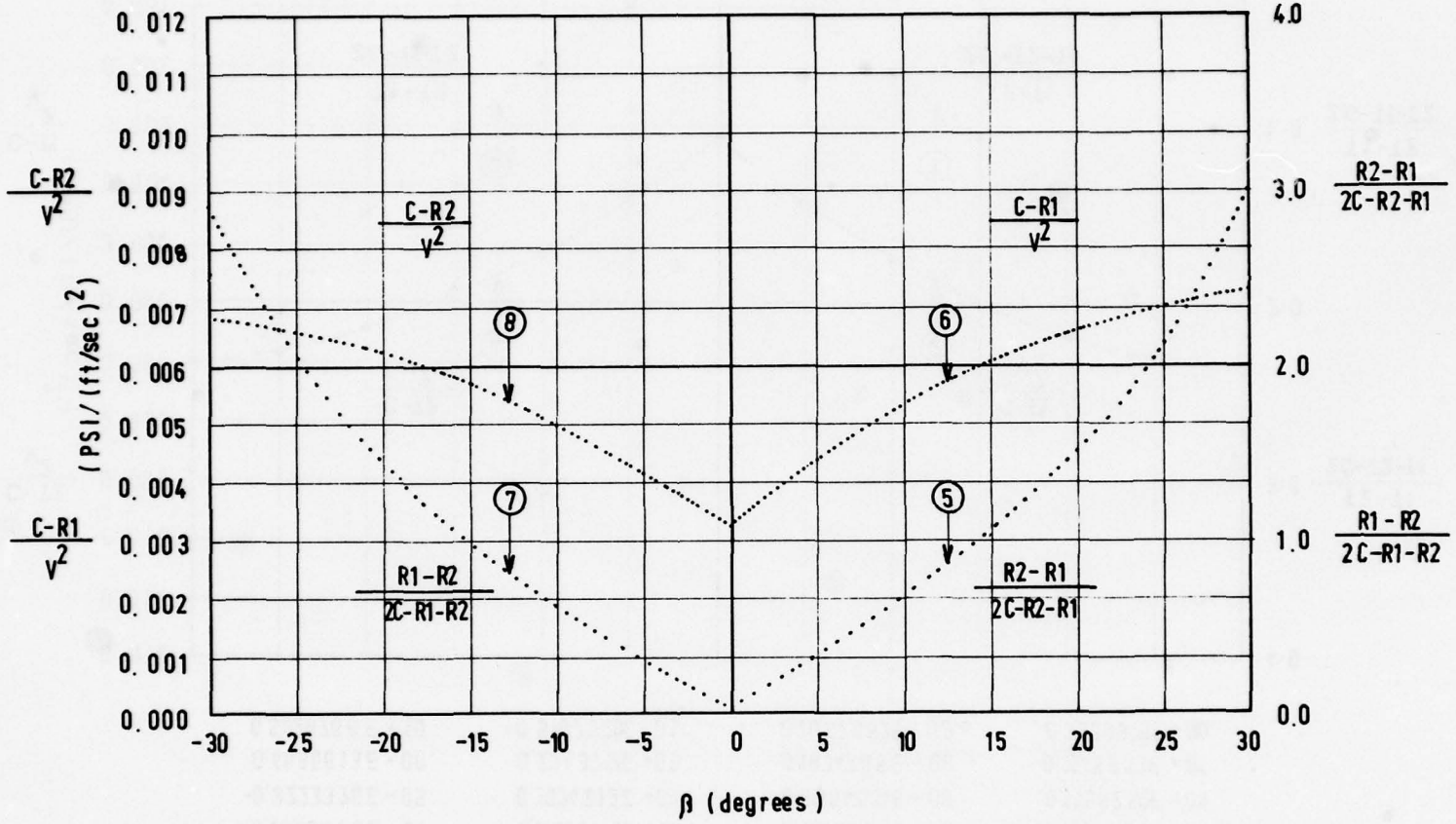


Figure 19 - Pre Calibration of Tube 11 in Vertical-Radial Plane

④	③	②	①
0.3298759E - 02	0.1367188E - 01	0.3300548E - 02	-0.2856445E - 01
-0.2003312E - 03	-0.1603516E + 02	0.2012849E - 03	0.1588281E + 02
0.1344830E - 05	0.5781250E + 00	0.5438924E - 06	-0.4843750E + 00
0.2777670E - 06	0.1066406E + 01	-0.1988374E - 06	-0.1015625E + 01
0.5034963E - 08	-0.1977539E + 00	0.3346941E - 08	0.1848145E + 00

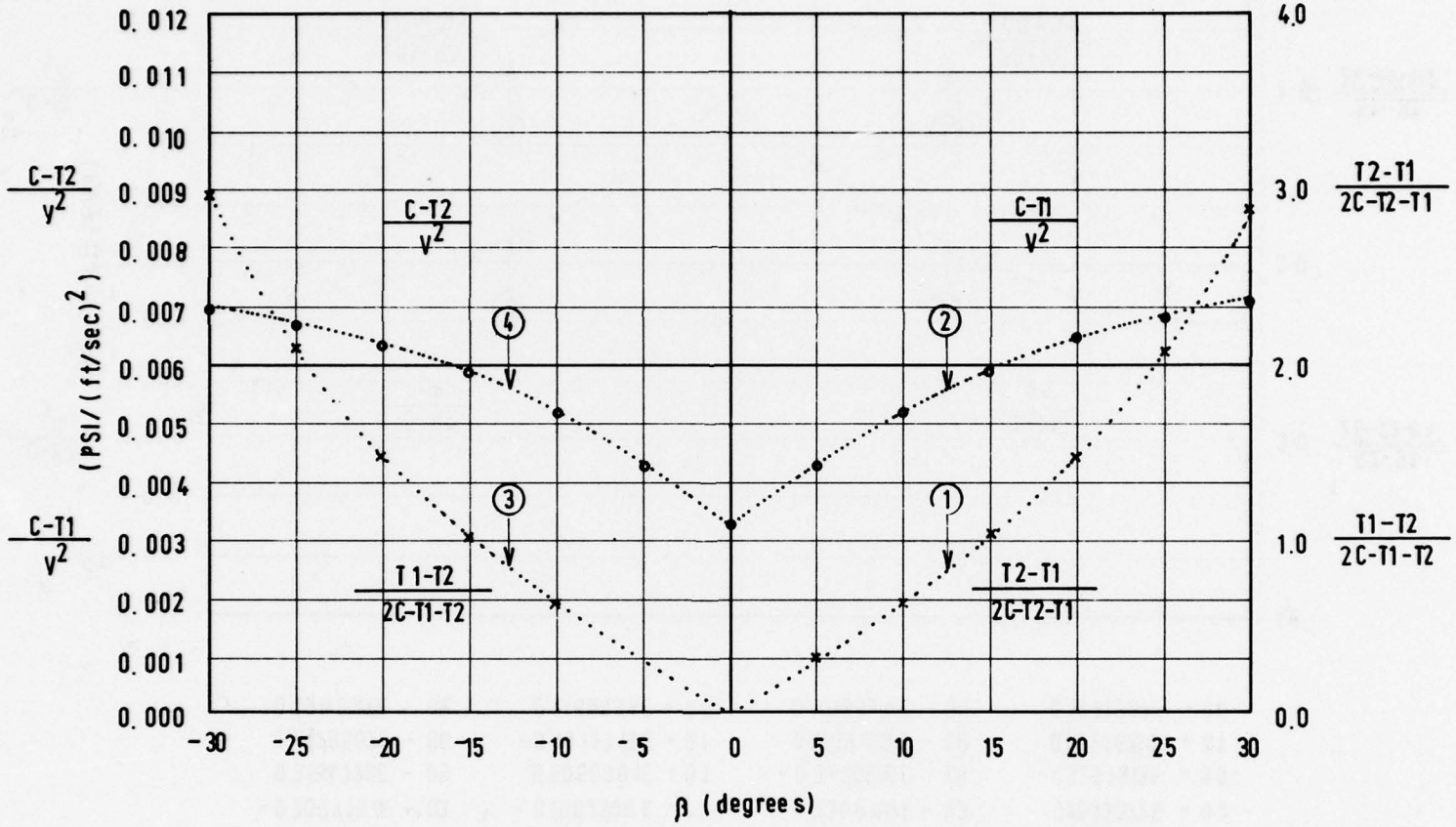


Figure 20 -Pre Calibration of Tube 12 in Horizontal-Tangential Plane

⑧ 0.3191948E - 02	⑦ 0.7377930E + 00	⑥ 0.3202319E - 02	⑤ -0.6367188E + 00
-0.2027154E - 03	-0.1962500E + 02	0.2359152E - 03	0.1663672E + 02
0.3054738E - 05	0.5050781E + 01	-0.3430992E - 05	-0.9257813E + 00
0.4479662E - 06	-0.1011719E + 01	-0.6519258E - 08	-0.1015625E + 01
0.8963980E - 08	0.1169434E + 00	0.1018634E - 09	0.1921387E + 00

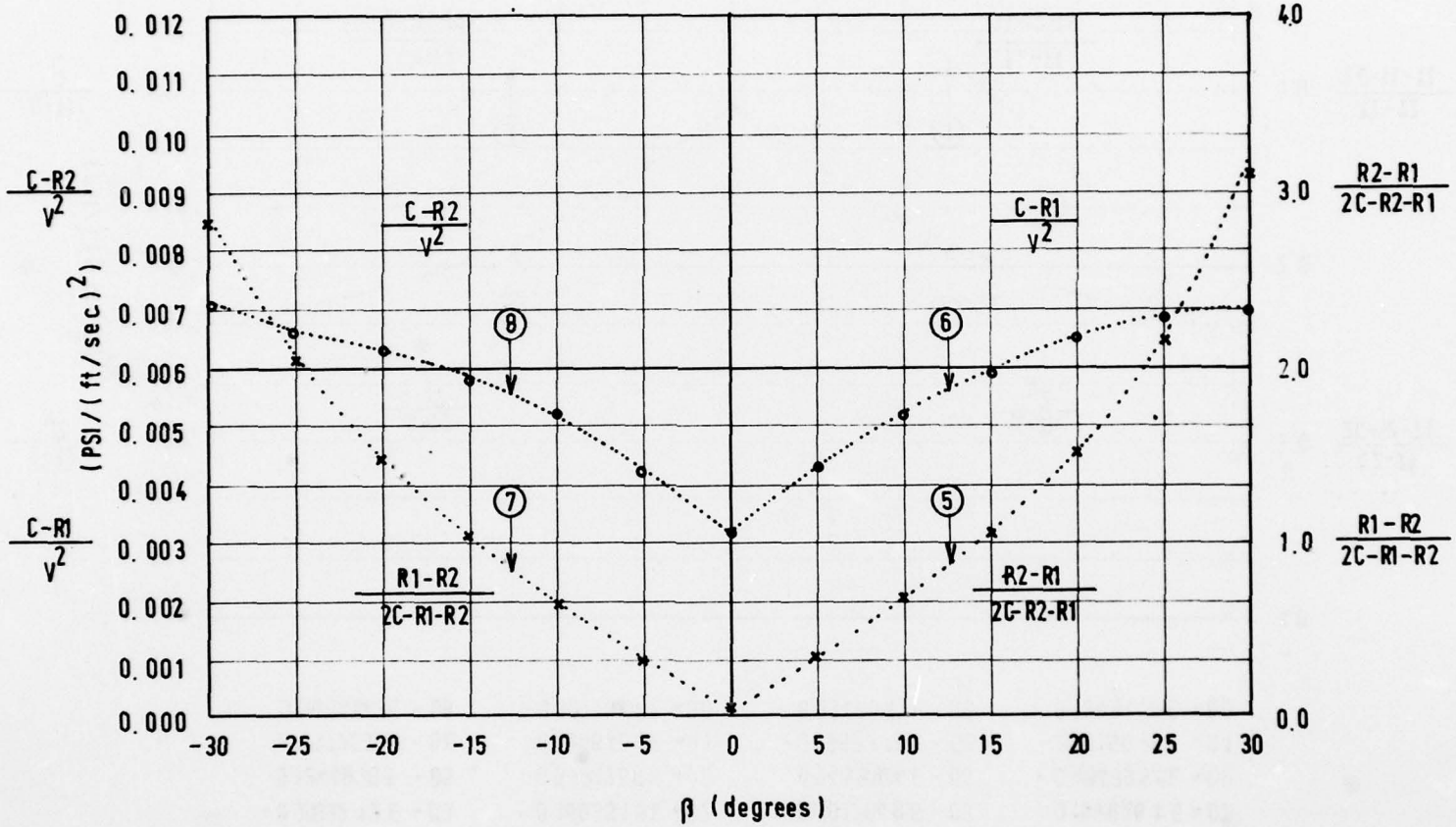


Figure 21 - Pre Calibration of Tube 12 in Vertical - Radial Plane

④ 0.3080606E - 02	③ 0.6567383E - 01	② 0.3104389 E - 02	① -0.1101074E + 00
-0.1978576E - 03	-0.1818799 E + 02	0.1864024E - 03	0.1858447 E + 02
-0.7338822E - 06	0.3697266E + 01	-0.5438924 E - 06	-0.3731689 E + 01
0.8853385E - 07	-0.2628326E + 00	-0.8859206E - 07	0.2413635 E + 00

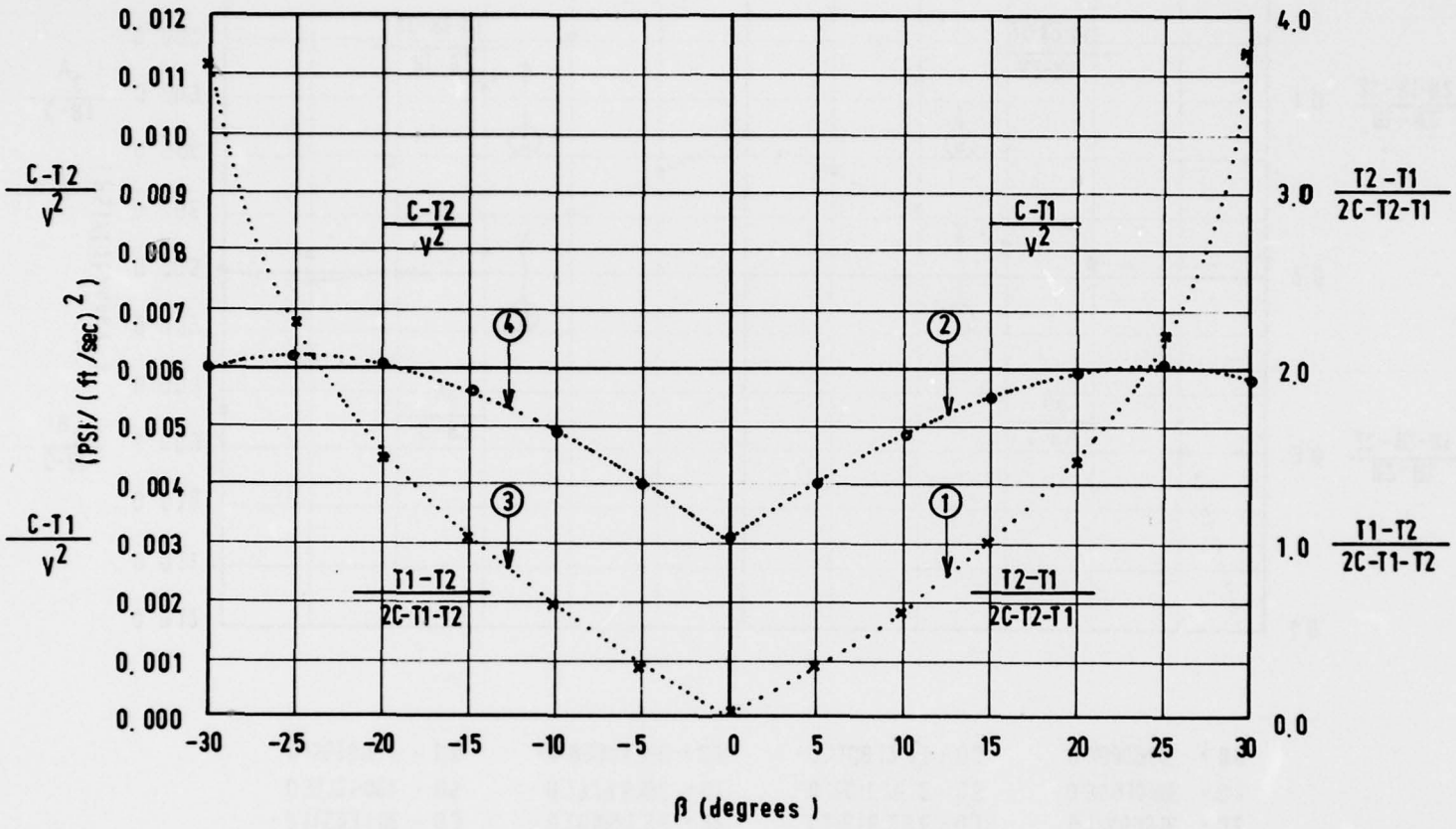


Figure 22 -Pre Calibration of Tube 13 in Horizontal - Tangential Plane at 6 feet per second

⑧	⑦	⑥	⑤
0.3547251E - 02	0.2677246E + 01	0.3564000E - 02	-0.2342041E + 01
-0.1159310E - 03	-0.2510913E + 02	0.1181625E - 03	0.1740381E + 02
0.3315508E - 05	0.7379639E + 01	0.1601875 E - 05	-0.3491699E + 01
0.1551816 E - 06	-0.9294434E + 00	-0.1108128 E - 06	0.2680969E + 00

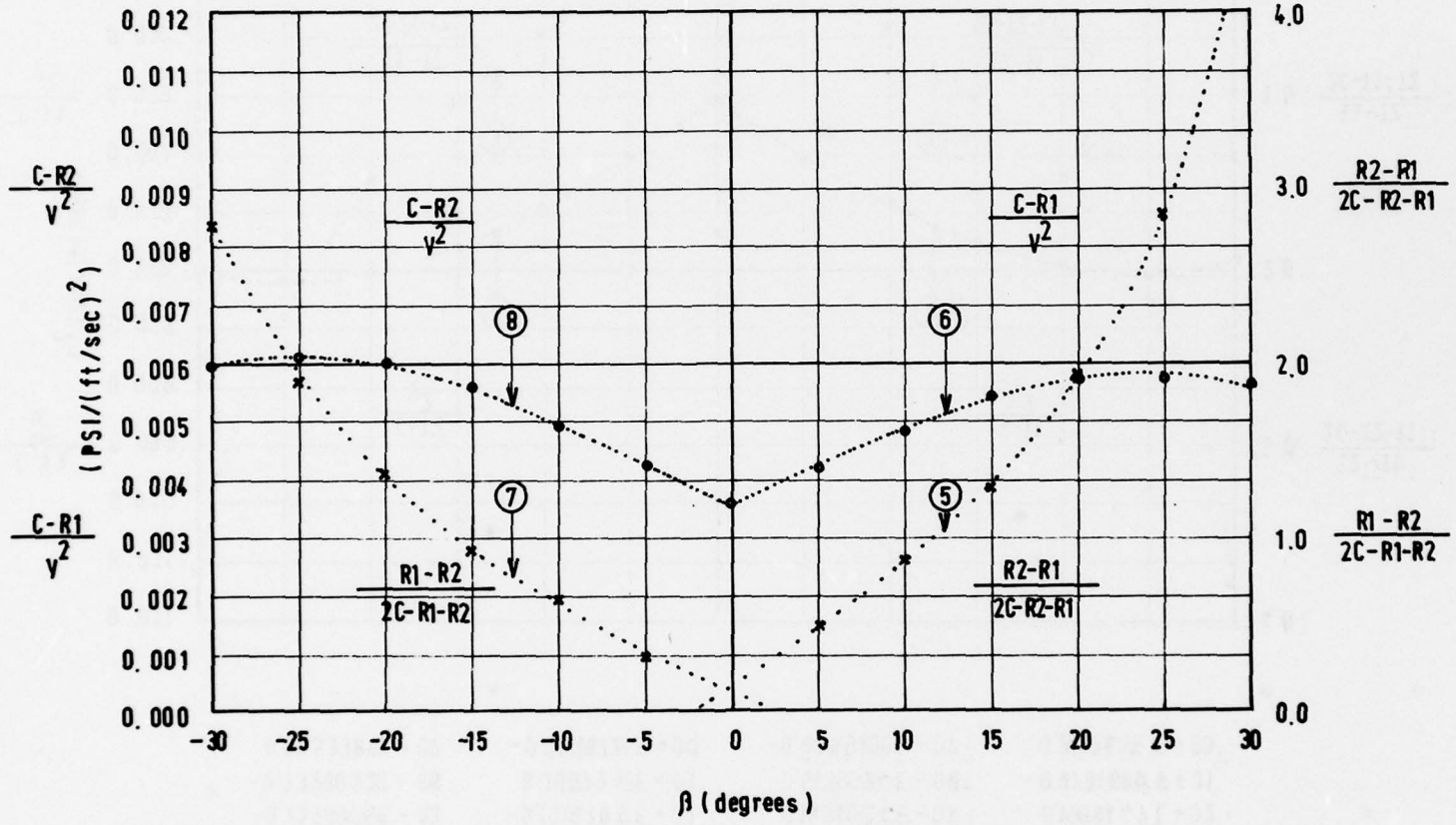


Figure 23 -Pre Calibration of Tube 13 in Vertical -Radial Plane at 6 feet per second

④ 0.3183007E - 02	③ 0.1423340E +00	② 0.3211558E - 02	① -0.5444336E-01
-0.1978651E - 03	-0.1755957E +02	0.1642965E - 03	0.1736597 E +02
-0.1158565 E - 05	0.3176270E +01	0.1031905E - 05	-0.3000488 E +0 1
0.4420872E - 07	-0.2053223E +00	-0.8854840E - 07	0.1623535 E +00

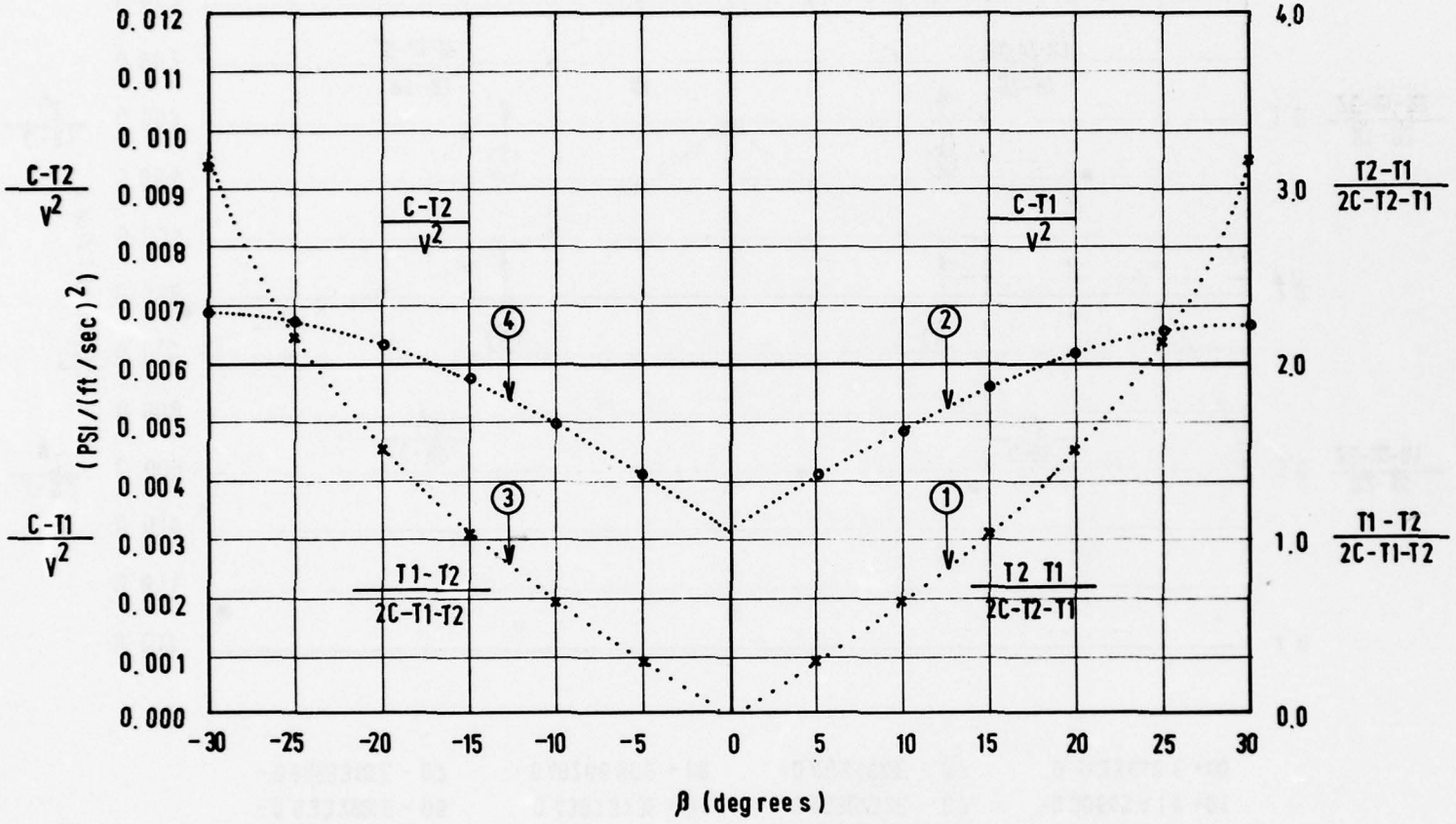


Figure 24 -Pre Calibration of Tube 13 in Horizontal-Tangential Plane at 11 feet per second

⑧ 0.3088057E - 02	⑦ 0.2329102E + 00	⑥ 0.3116310E - 02	⑤ -0.1535645E +00
-0.2322756E - 03	-0.1828638E + 02	0.1882501E - 03	0.1789111E +02
-0.6333299E - 05	0.4307373E + 01	0.2980232E - 07	-0.3064941E +01
-0.8888310E - 07	-0.4826660E + 00	-0.6635673E - 07	0.1523438E +00

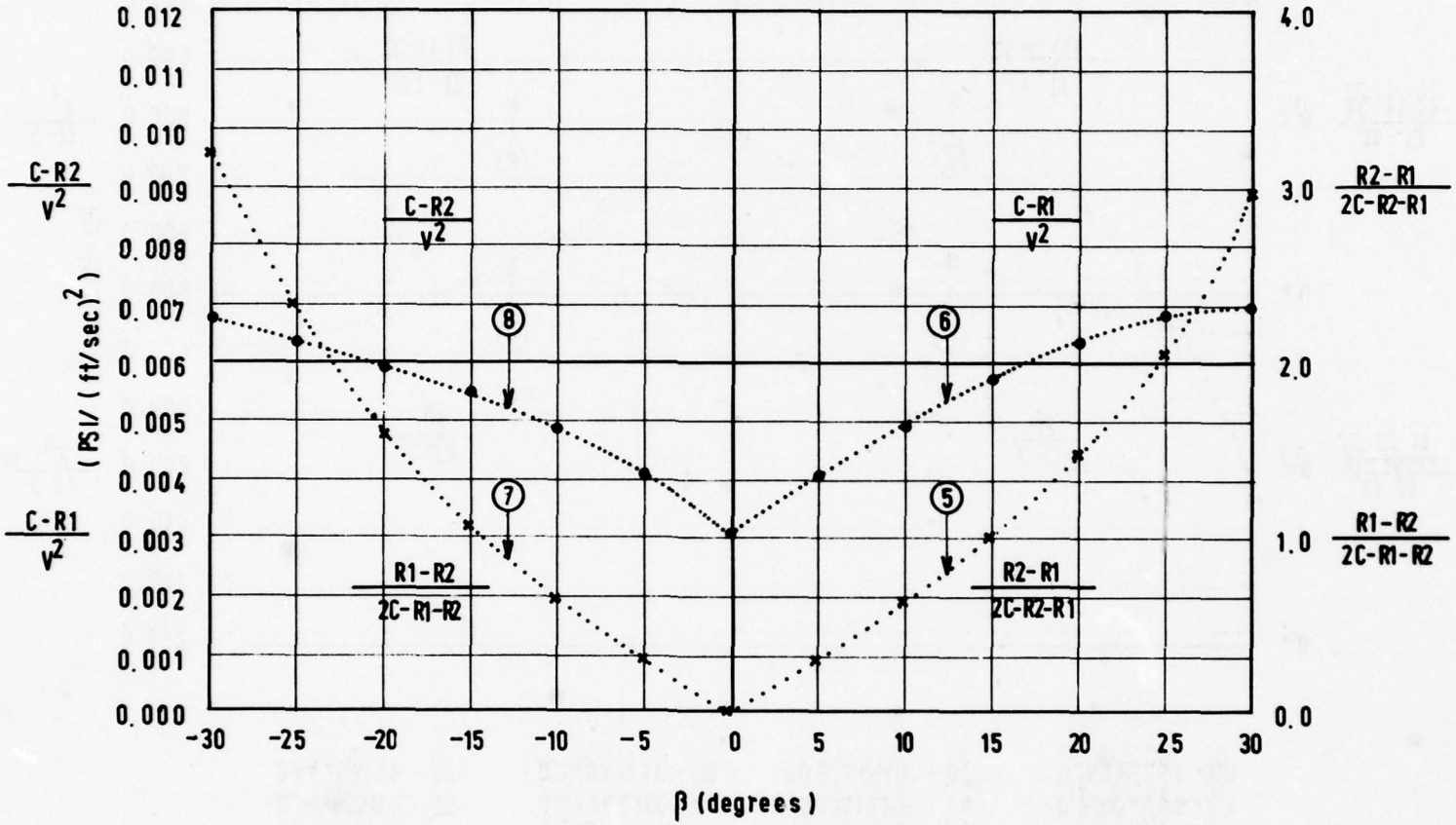


Figure 25 -Pre Calibration of Tube 13 in Vertical-Radial Plane at 11 feet per second

④ 0.3300250E - 02	③ 0.1960449E + 00	② 0.3297269E - 02	① -0.2292480E + 00
-0.2353787E - 03	- 0.1518750E + 02	0.2198815E - 03	0.1694141E + 02
-0.2752990E - 05	- 0.1214944E + 01	- 0.3226101E - 05	-0.1453125E + 01
0.7939525E - 07	0.2136719E + 01	-0.2095476E - 08	-0.7968750E + 00
0.1717126E - 08	- 0.3740234E + 00	0.2910383E - 10	0.1682129E + 00

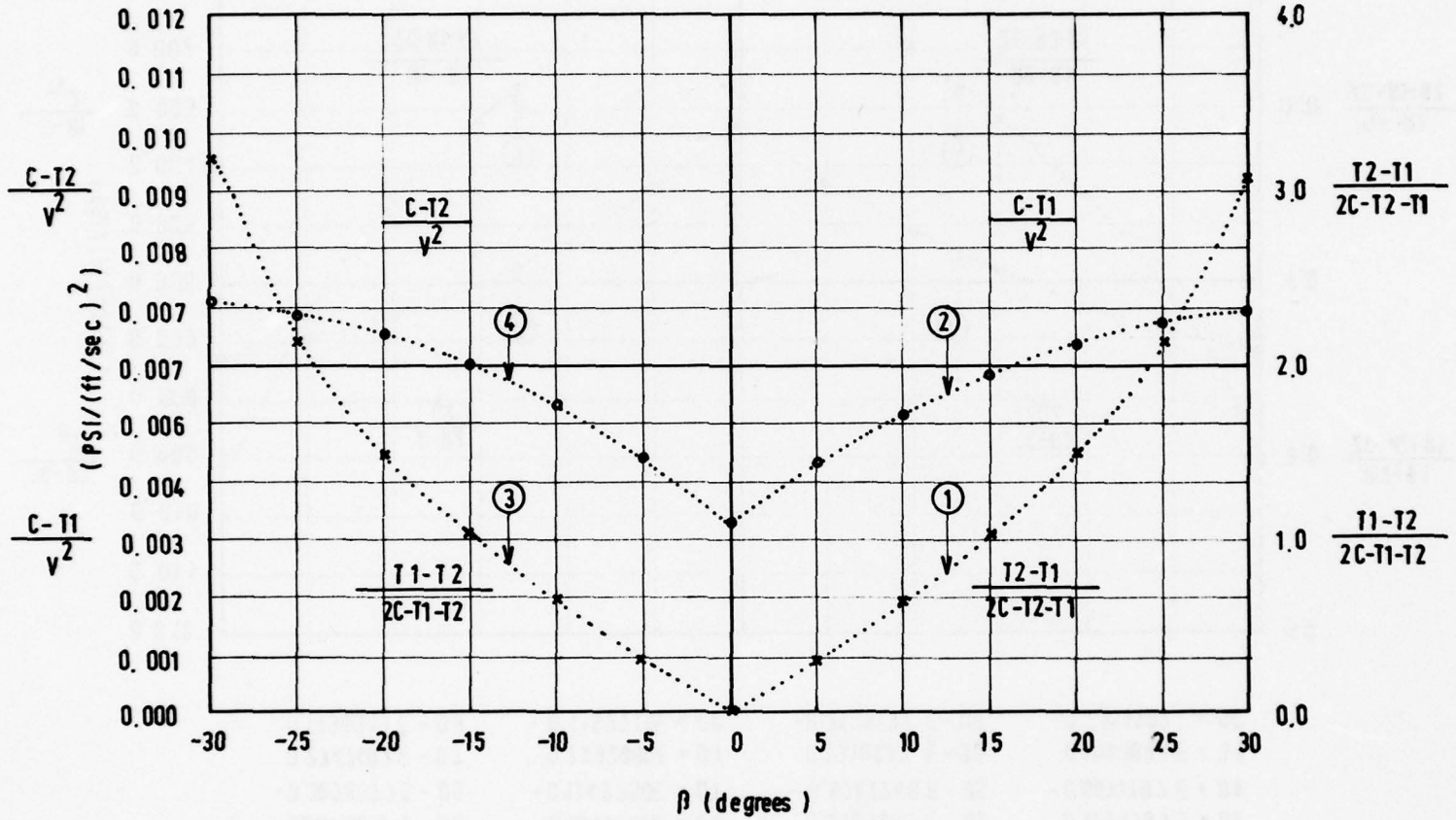


Figure 26 -Pre Calibration of Tube 13 in Horizontal-Tangential Plane at 20 feet per second

⑧	⑦	⑥	⑤
0.3298700E - 02	0.3588867E + 00	0.3283441E - 02	-0.4277344E + 00
-0.2411008 E - 03	-0.1519141E + 02	0.2205372 E - 03	0.1991797 E + 02
-0.3870577E - 05	-0.1343750E + 01	- 0.5047768 E - 05	- 0.6617187 E + 01
0.2747402E - 07	0.2292969E + 01	0.1310837 E - 06	0.1996094E + 01
0.1236913 E - 08	- 0.4199219E + 00	-0.2139132 E - 08	- 0.2954102E + 00

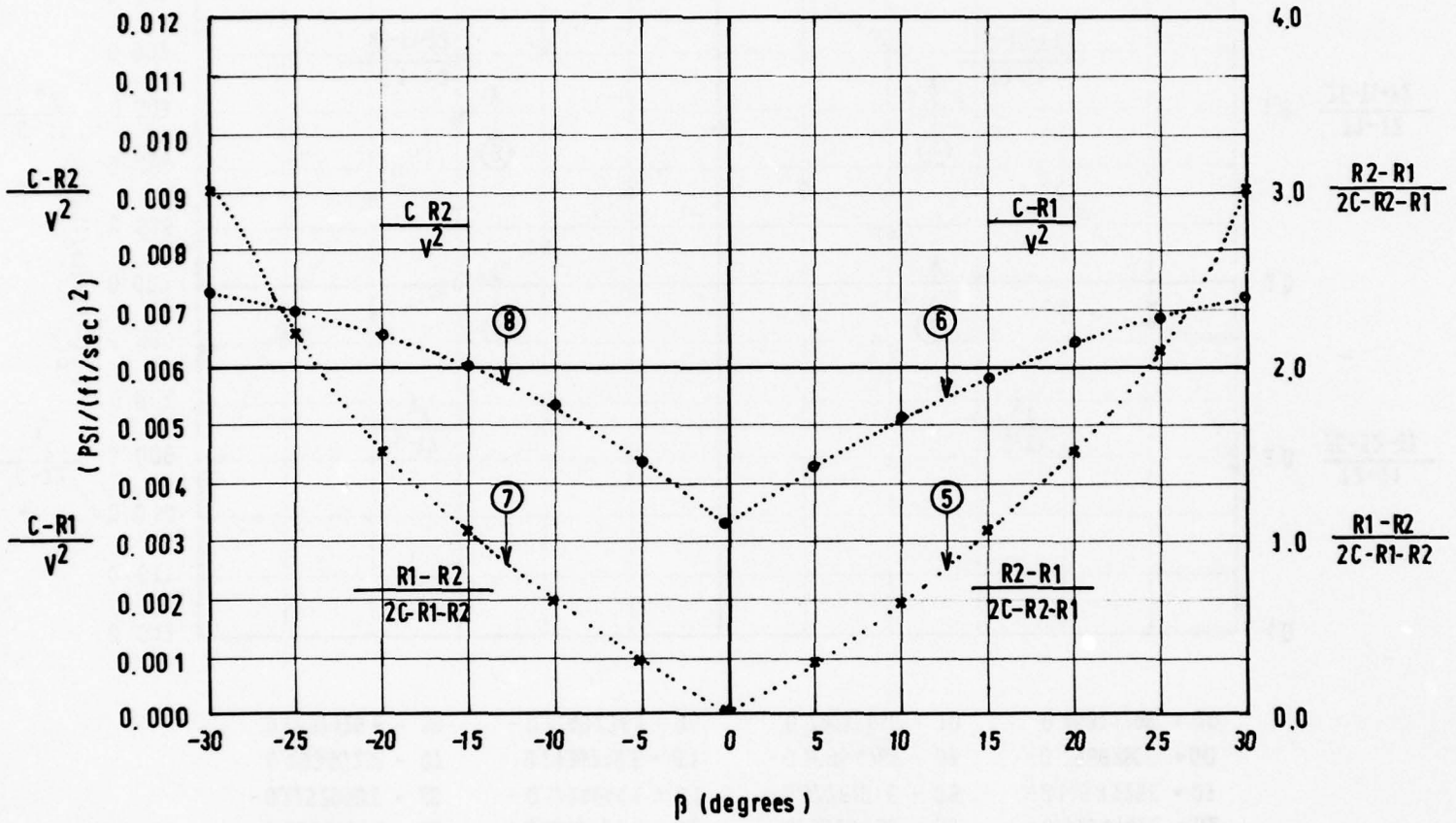


Figure 27 -Pre Calibration of Tube 13 in Vertical-Radial Plane at 20 feet per second

④	③	②	①
0.3380656E-02	0.2585449E+00	0.3373563E-02	-0.2485352E+00
-0.2305359E-03	-0.1667456E+02	0.2126358E-03	0.1787402E+02
-0.3013760E-05	0.2091797E+01	-0.2298504E-05	-0.3038818E+01
0.2198794E-07	0.5200195E-01	-0.2201705E-07	0.1647949E+00

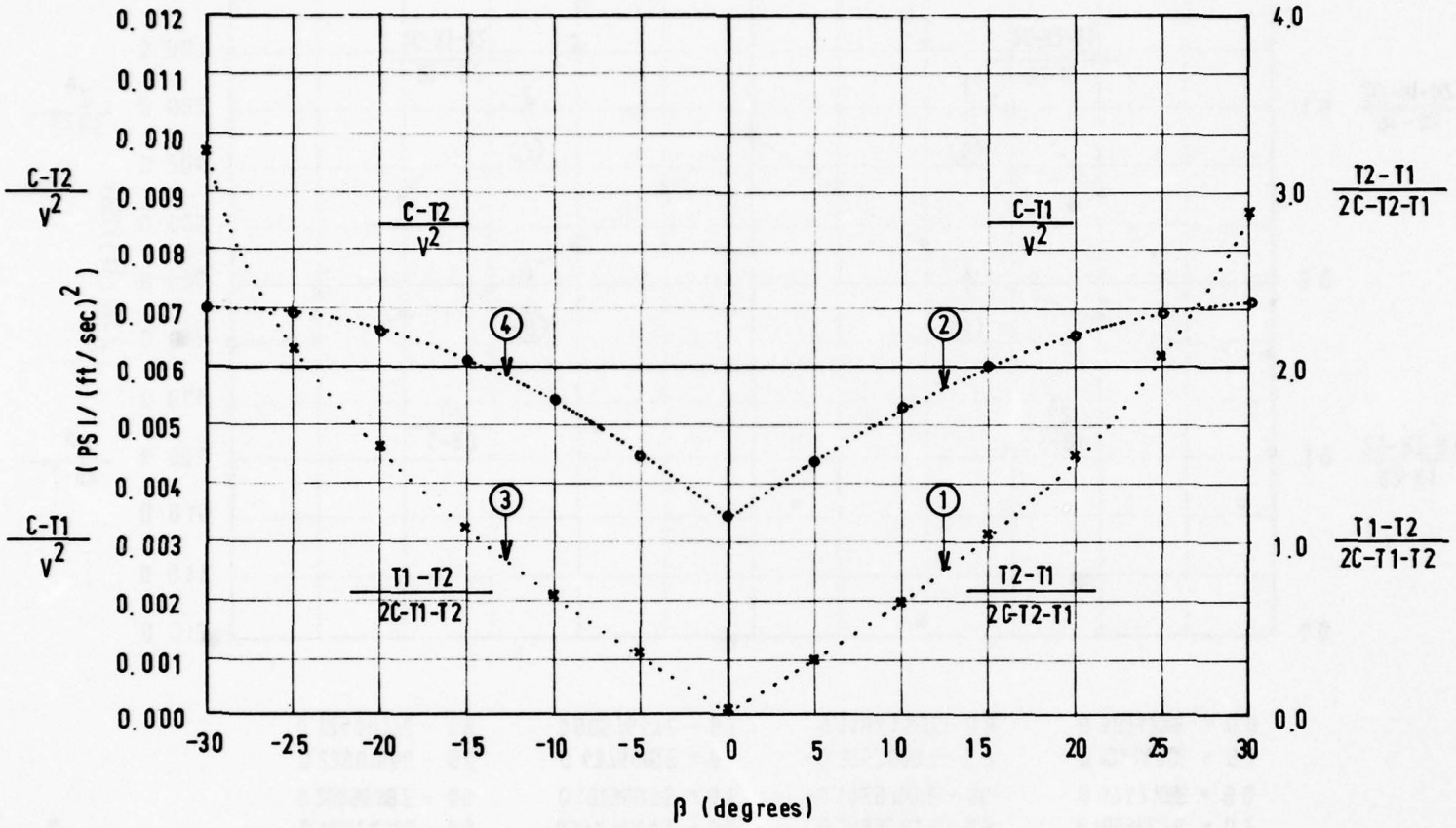


Figure 28 -Pre Calibration of Tube 15 in Horizontal-Tangential Plane

⑧ 0.3388286E - 02	⑦ 0.2346191E + 00	⑥ 0.3396094E - 02	⑤ -0.2534180E + 00
-0.1861453E - 03	-0.1721094E + 02	0.2149343E - 03	0.1603125E + 02
0.2089888E - 05	0.1929687E + 01	-0.1929700E - 05	0.5742188E + 00
0.2398156E - 06	0.4375000E + 00	-0.6752089E - 07	-0.1941406E + 01
0.3245077E - 08	-0.9057617E - 01	0.1164153E - 08	0.3674316E + 00

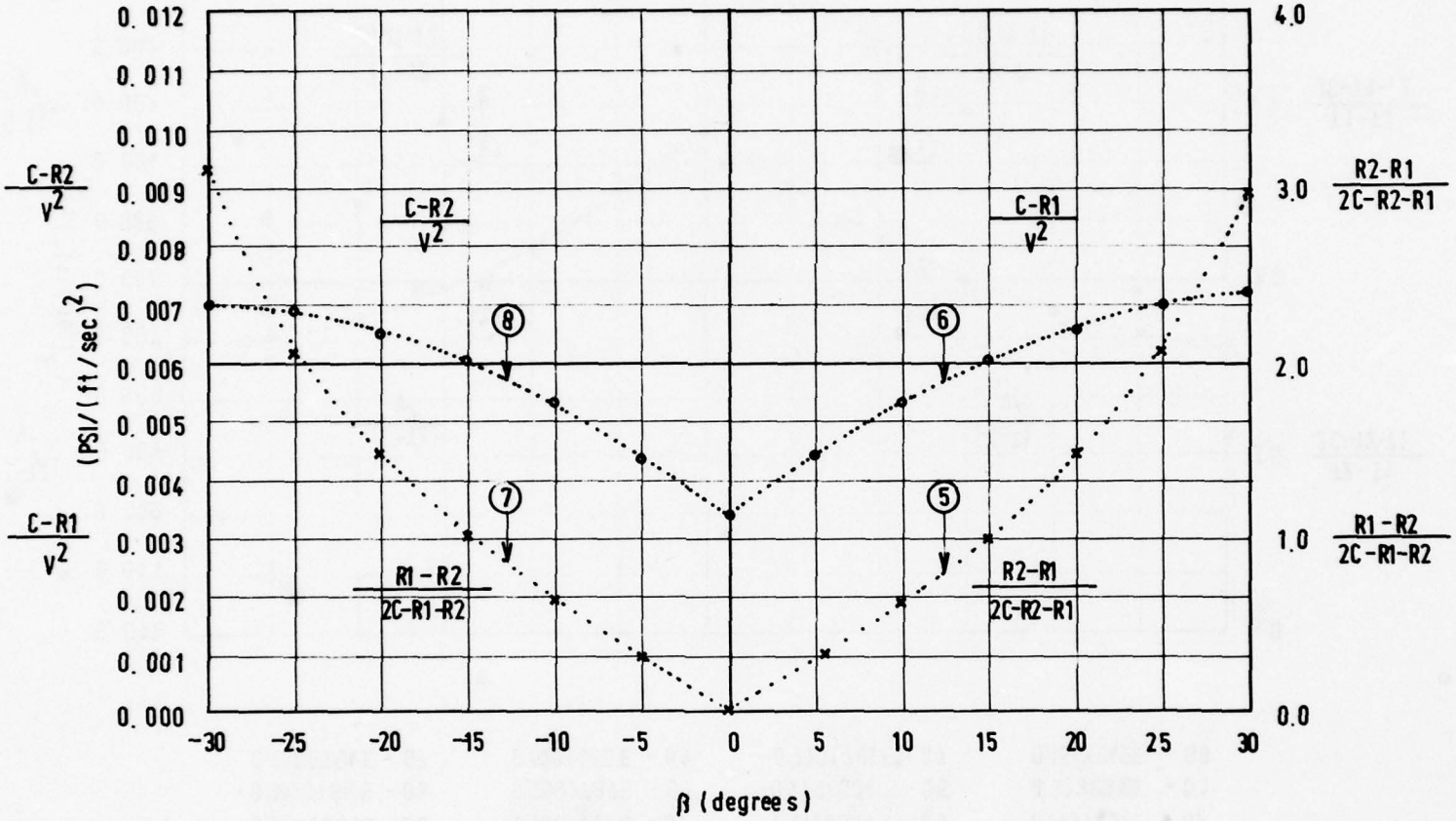


Figure 29 - Pre Calibration of Tube 15 in Vertical-Radial Plane

④	③	②	①
0.3493190E - 02	0.3872070E +00	0.3475130E - 02	-0.3598633E +00
-0.2081990E - 03	-0.1851172E +02	0.1186132E - 04	0.1648437E +02
0.1136214E - 05	0.7882813E +01	0.2884492E - 04	-0.1265625E +01
0.2882443E - 06	-0.5457031E +01	-0.1566485E - 05	0.4882813E +00
0.5558832E - 08	0.1312500E +01	0.2428715E - 07	-0.2382813E +00

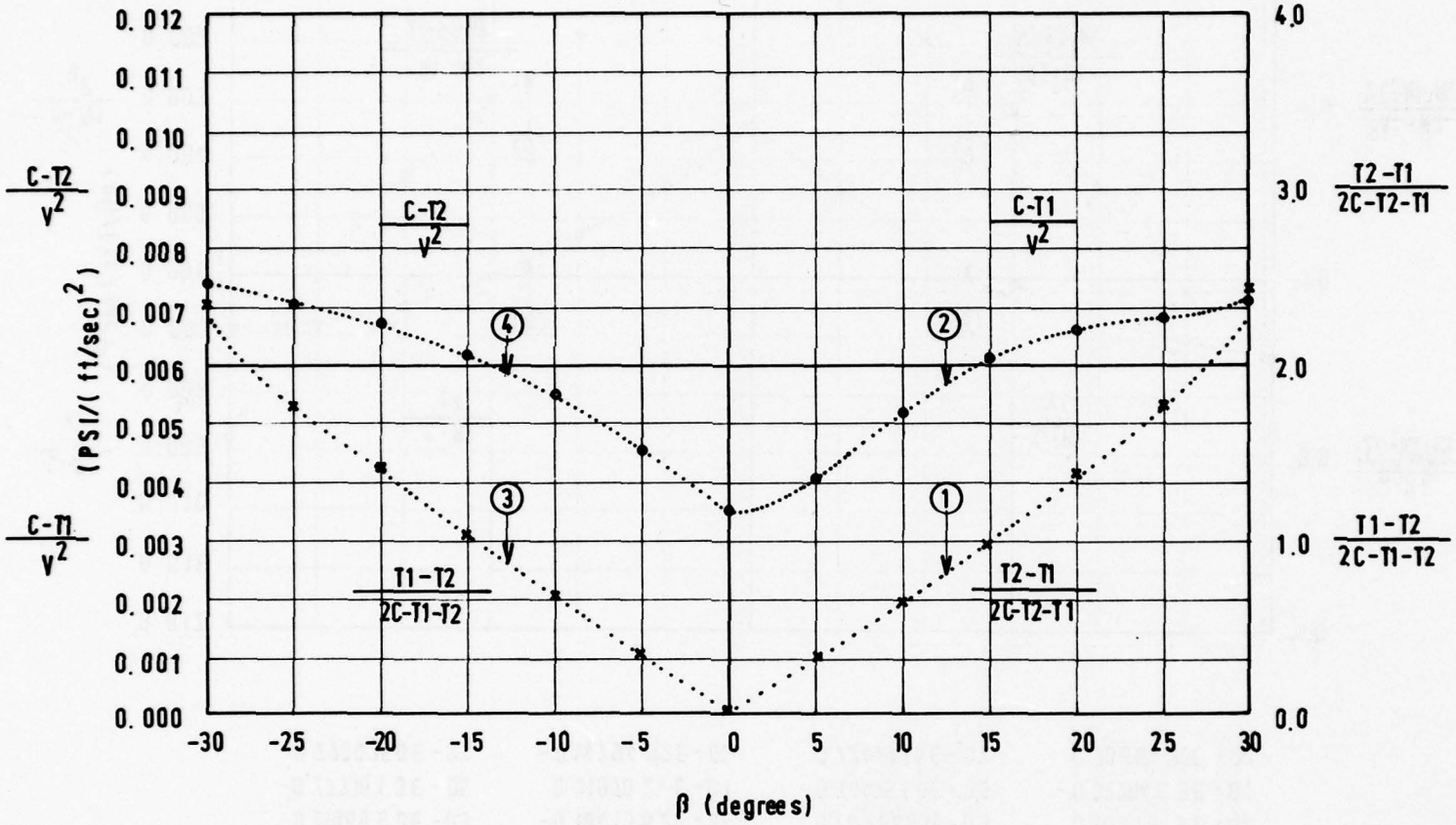


Figure 30 -Pre Calibration of Tube 17 Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3329577E-02	0.3349609E+00	0.3397405E-02	-0.4418945E+00
-0.2196990E-03	-0.1841162E+02	0.2426803E-03	0.1812180E+02
-0.2771616E-05	0.3197021E+01	-0.4440546E-05	-0.3220459E+01
0.2200250E-07	-0.1479492E+00	0.2240995E-07	0.2065430E+00

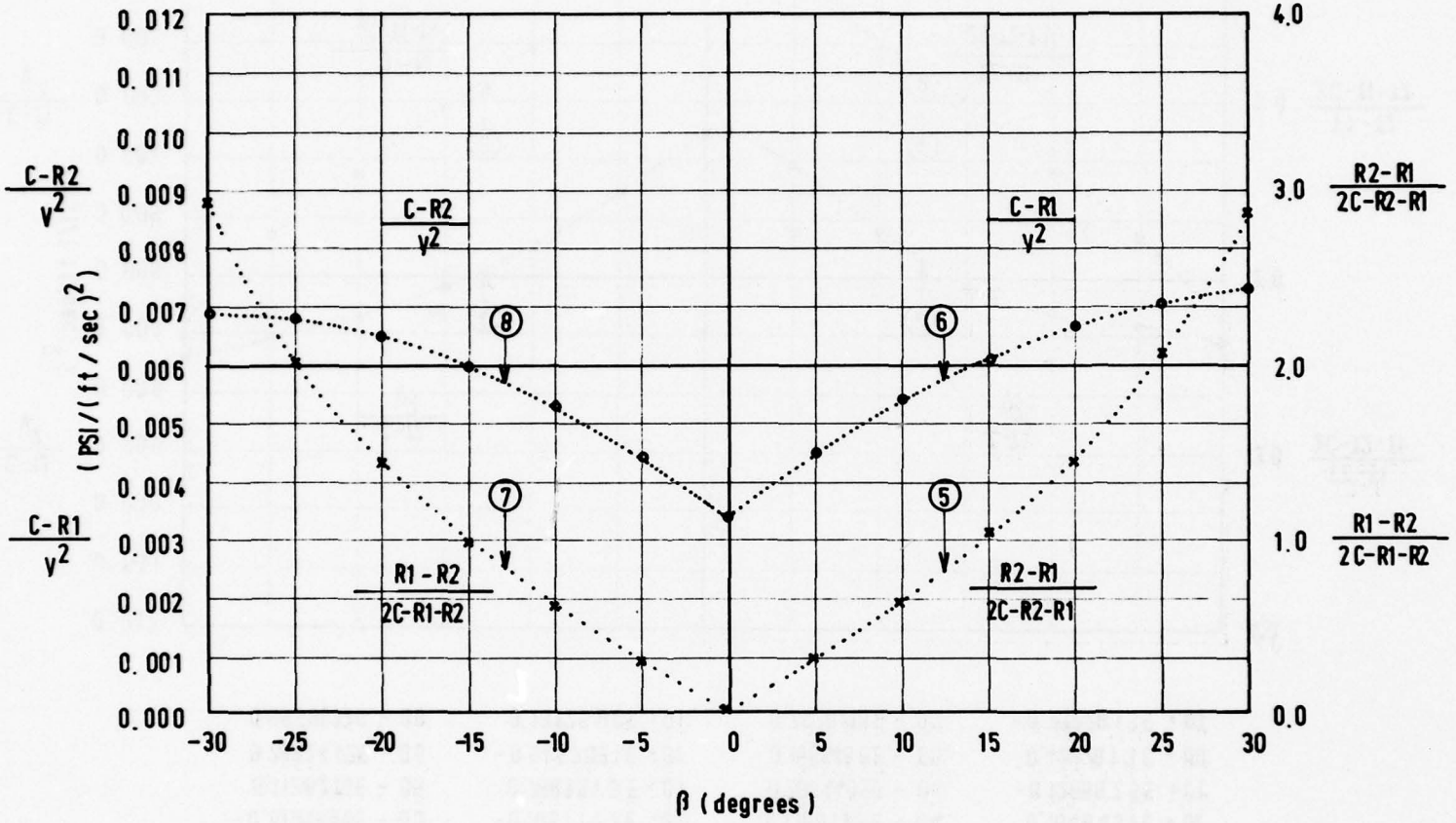


Figure 31 -Pre Calibration of Tube 17 in Vertical-Radial Plane

④	③	②	①
0.3398418E-02	0.1262207E+00	0.3400505E-02	-0.1274414E+00
-0.2008080E-03	-0.1638672E+02	0.1913309E-03	0.1505078E+02
0.1221895E-05	0.7578125E+00	0.2875924E-05	0.8203125E+00
0.2717134E-06	0.1082031E+01	-0.3110617E-06	-0.1582031E+01
0.4976755E-08	-0.2036133E+00	0.4874892E-08	0.2426758E+00

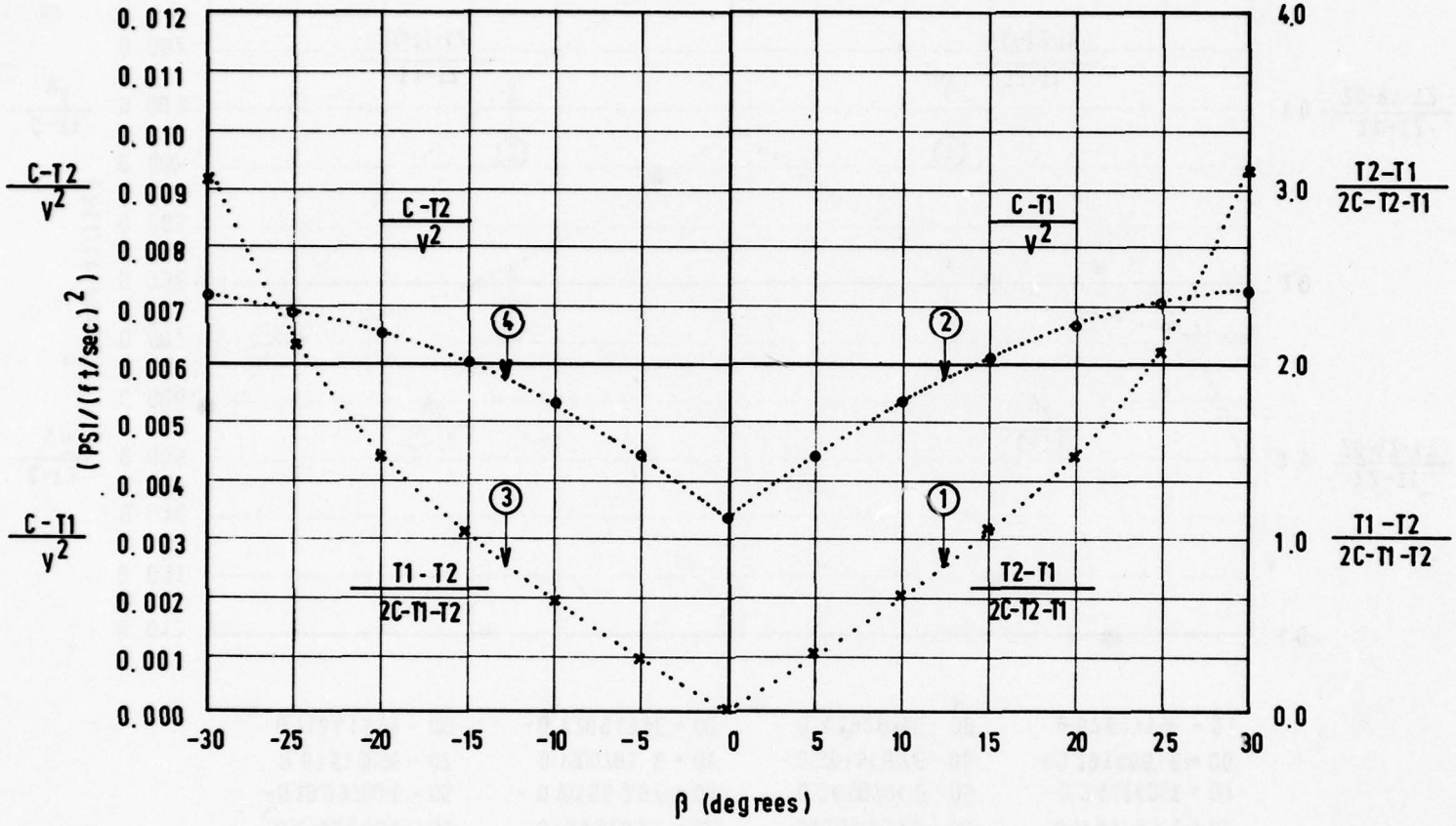


Figure 32 -Pre Calibration of Tube 18 in Horizontal-Tangential Plane

④ 0.3396094E-02	③ 0.2163086E+00	② 0.3403485E-02	① -0.2363281E+00
-0.2149343E-03	-0.1549609E+02	0.1638532E-03	0.1741797E+02
-0.1929700E-05	-0.1015625E+00	0.3650784E-05	-0.2441406E+01
0.6752089E-07	0.1300781E+01	-0.3015157E-06	-0.1914063E+00
0.1164153E-08	-0.2209473E+00	0.4292815E-08	0.5761719E-01

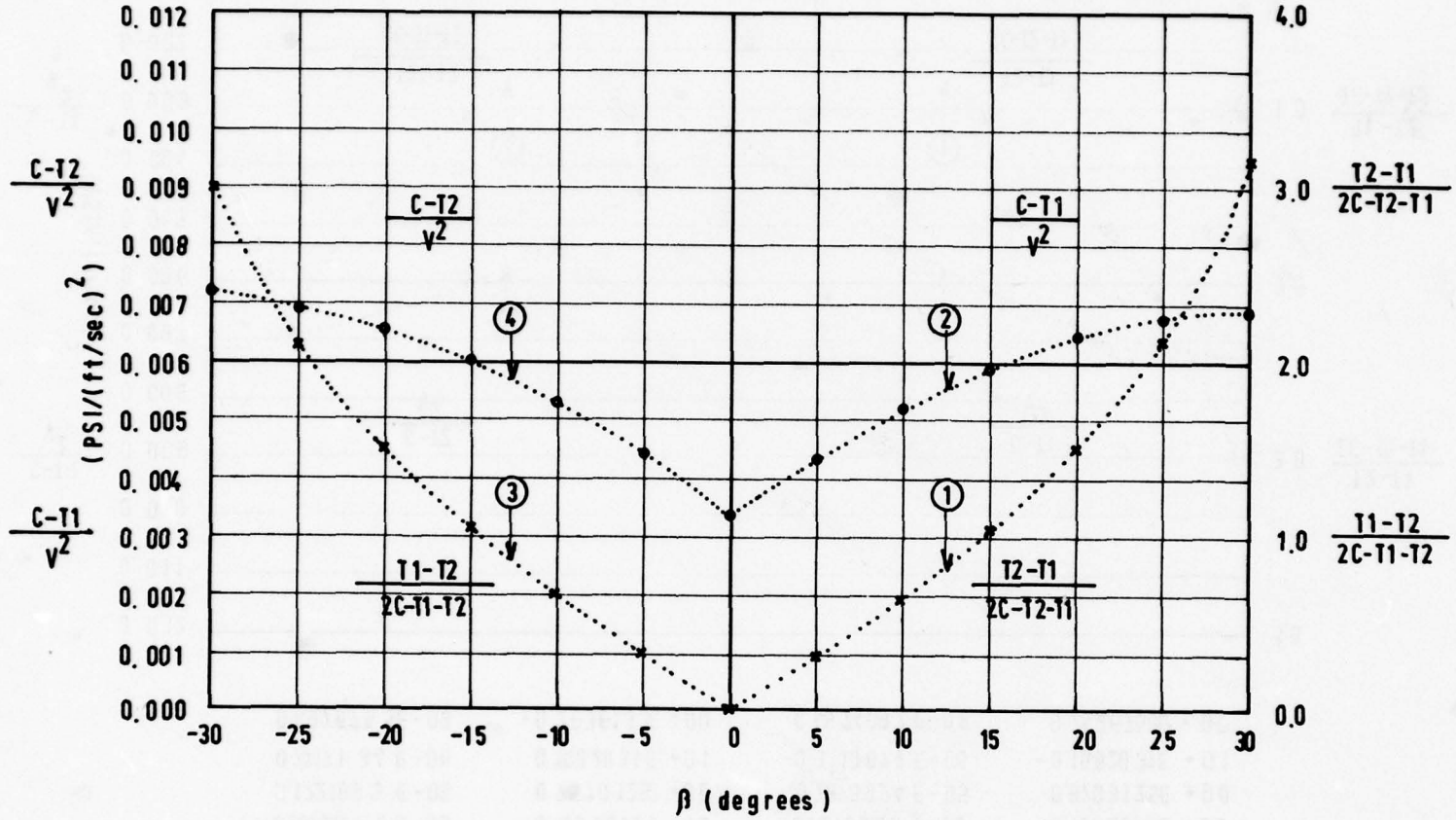


Figure 33 -Pre Calibration of Tube 20 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3391564E-02	0.2890625E+00	0.3383517E-02	-0.1347656E+00
-0.1815557E-03	-0.1687109E+02	0.1041889E-03	0.1528906E+02
0.2406538E-05	0.1804687E+01	0.1442432E-04	0.8007813E+00
0.2088491E-06	0.4570313E+00	-0.8982606E-06	-0.1910156E+01
0.2037268E-08	-0.8813477E-01	0.1469743E-07	0.3466797E+00

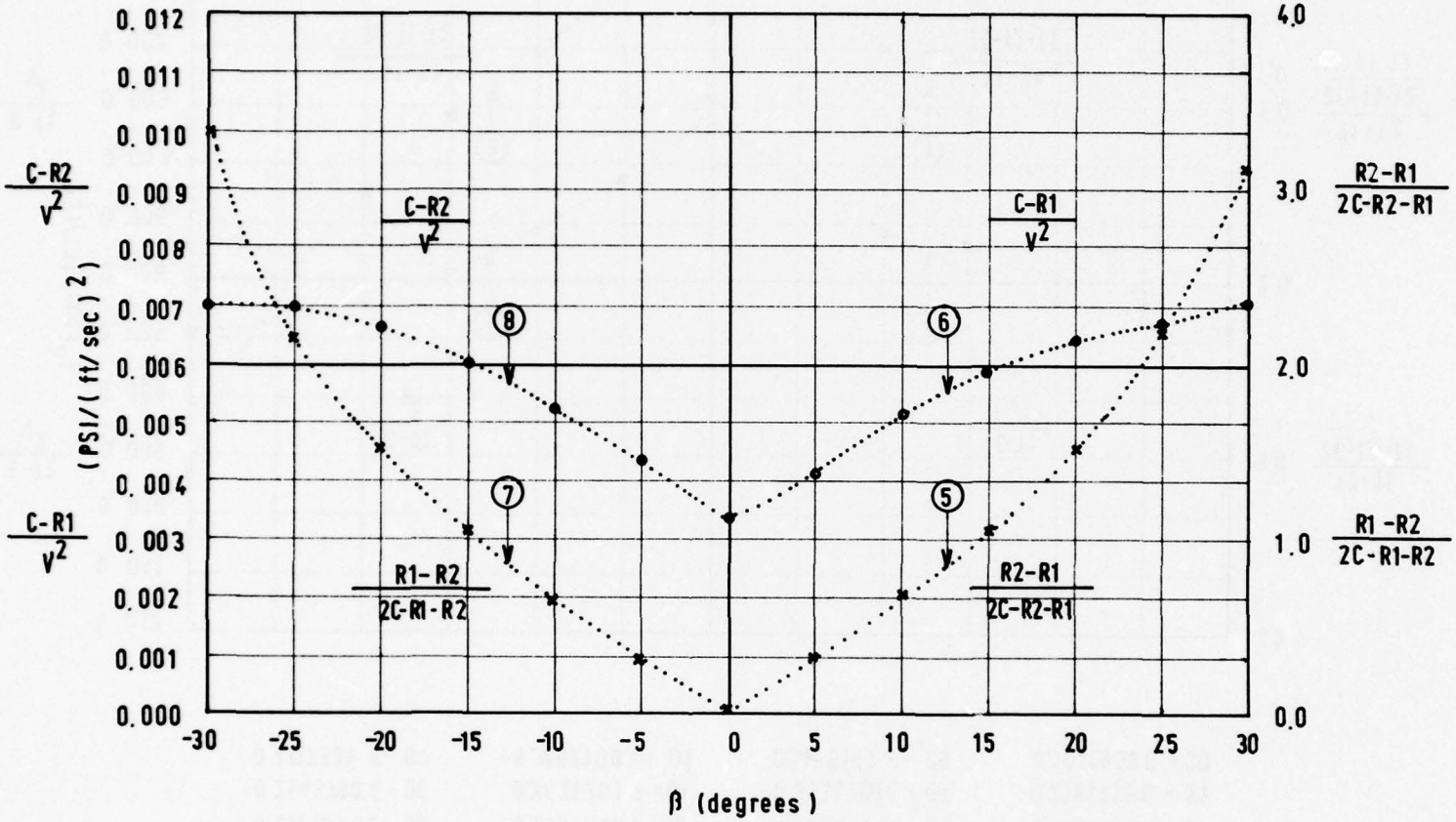


Figure 34-Pre Calibration of Tube 20 in Vertical-Radial Plane

④	③	②	①
0.3194928E-02	0.1821289E+00	0.3187895E-02	-0.1318359E+00
-0.2161078E-03	-0.1687968E+02	0.2258271E-03	0.1721240E+02
-0.2443790E-05	0.2421387E+01	-0.3535300E-05	-0.2761475E+01
0.2197339E-07	-0.3662109E-01	0.1455192E-09	0.1040039E+00

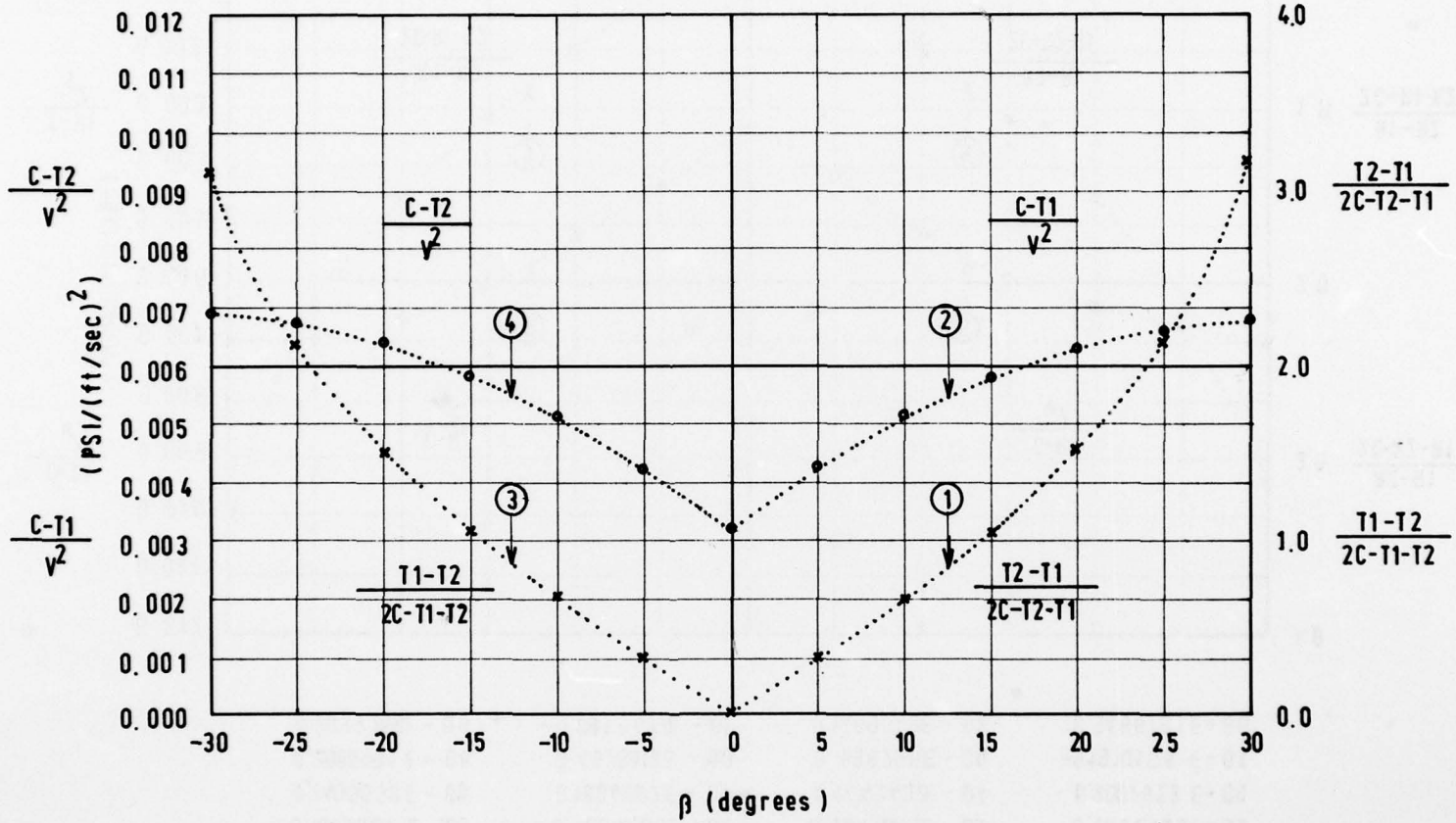


Figure 35 -Pre Calibration of Tube 21 in Horizontal-Tangential Plane

⑧ 0.3199697 E - 02	⑦ 0.1262207E + 00	⑥ 0.3190219E - 02	⑤ -0.1154785E + 00
- 0.2161227 E - 03	- 0.1721753E + 02	0.2221949E - 03	0.1640942 E + 02
- 0.2630055E - 05	0.2648193 E + 01	-0.3203750 E - 05	- 0.1962402E + 01
0.2201705 E - 07	- 0.6347656E - 01	0.1746230E - 09	- 0.5273438E - 01

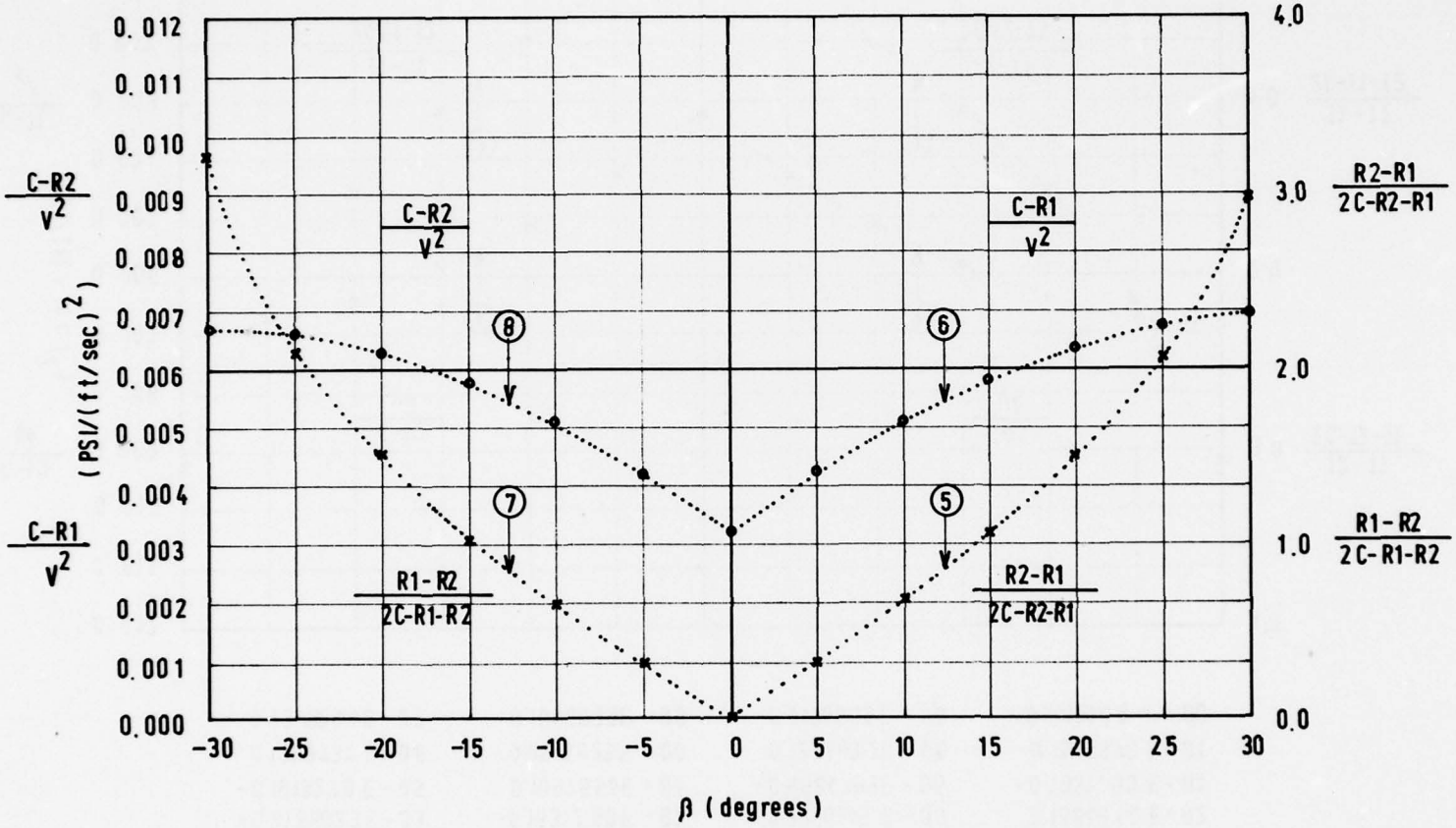


Figure 36 -Pre Calibration of Tube 21 in Vertical-Radial Plane

④ 0.3192484E-02	③ 0.5200195 E-01	② 0.3207386E-02	① -0.5395508E-01
-0.2166033E-03	-0.1631250E+02	0.2390146 E-03	0.1564844 E+02
-0.1013279 E-05	0.1097656E+01	-0.5684793E-05	-0.7031250 E-01
0.1359731 E-06	0.8515625E+00	0.1234002E-06	-0.1359375 E+01
0.2270099E-08	-0.1665039E+00	-0.2110028E-08	0.2412109 E+00

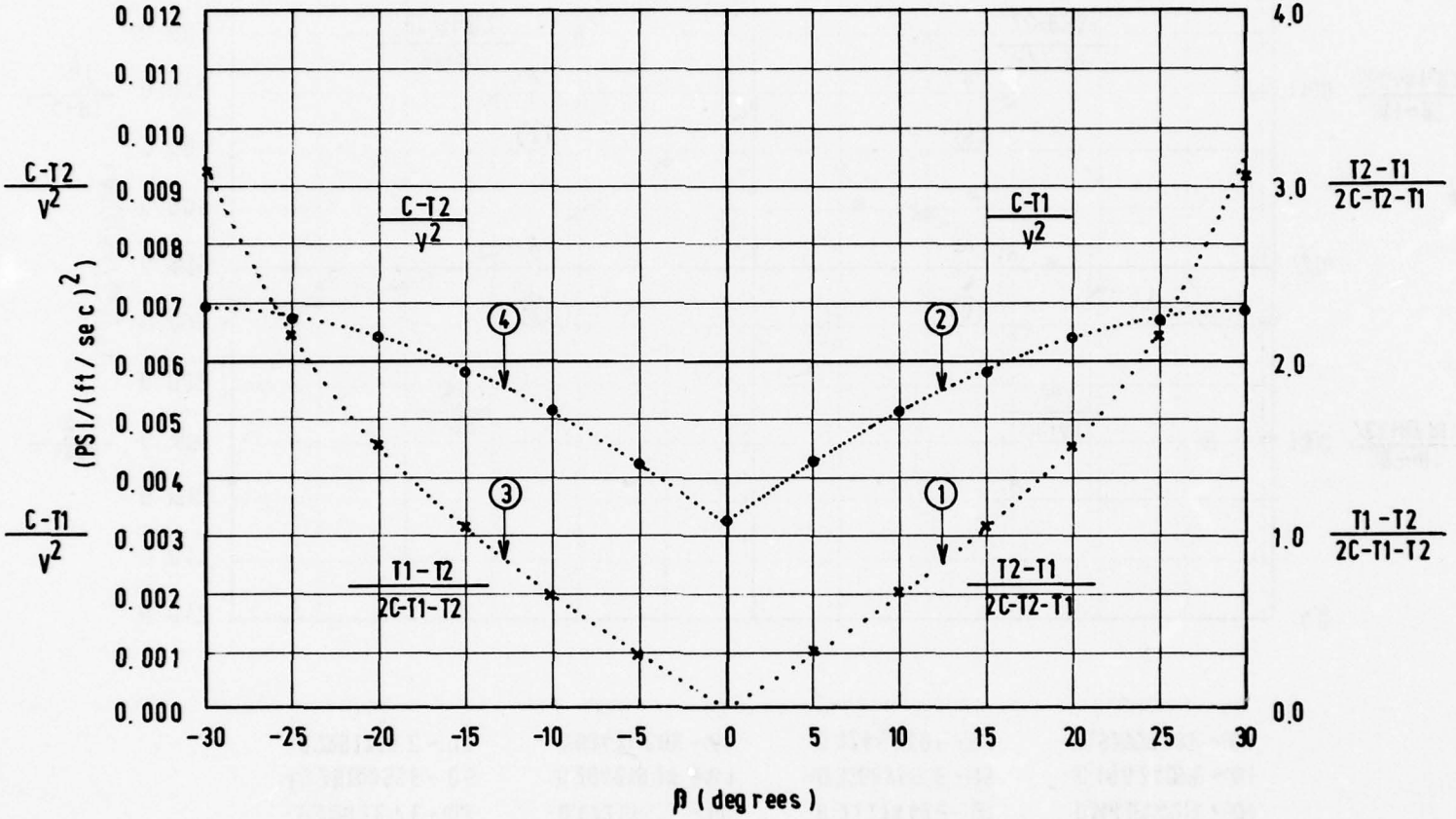


Figure 37 -Pre Calibration of Tube 22 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3293395E-02	0.5468750E-01	0.3298283E-02	-0.5688477E-01
-0.1885295E-03	-0.1623047E+02	0.1711249E-03	0.1485547E+02
0.5401671E-06	0.9453125E+00	0.3561378E-05	0.9648438E+00
0.1941808E-06	0.9414063E+00	-0.3154855E-06	-0.1808594E+01
0.3317837E-08	-0.1730957E+00	0.4903995E-08	0.3220215E+00

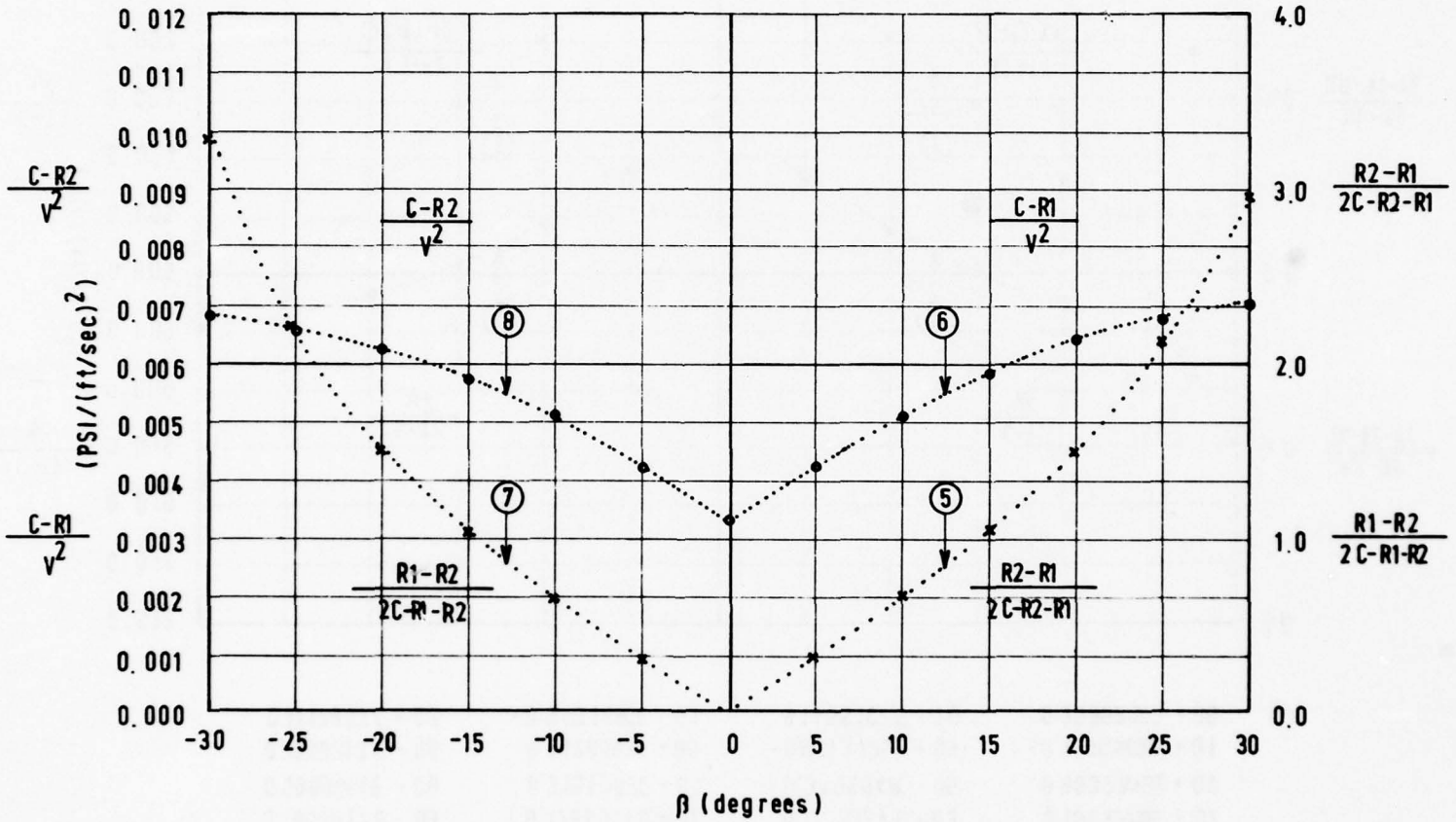


Figure 38 -Pre Calibration of Tube 22 in Vertical-Radial Plane

④	③	②	①
0.3286183E - 02	0.1503906E + 00	0.3290236E - 02	-0.1511230E + 00
-0.1957417E - 03	-0.1706641E + 02	0.2270937E - 03	0.1543750E + 02
0.5960464E - 06	0.2164062E + 01	-0.3108848E - 05	0.8632813E + 00
0.2016313E - 06	0.3476563E + 00	-0.9313226E - 09	-0.1976563E + 01
0.3317837E - 08	-0.8471680E - 01	0.1455192E - 10	0.3635254E + 00

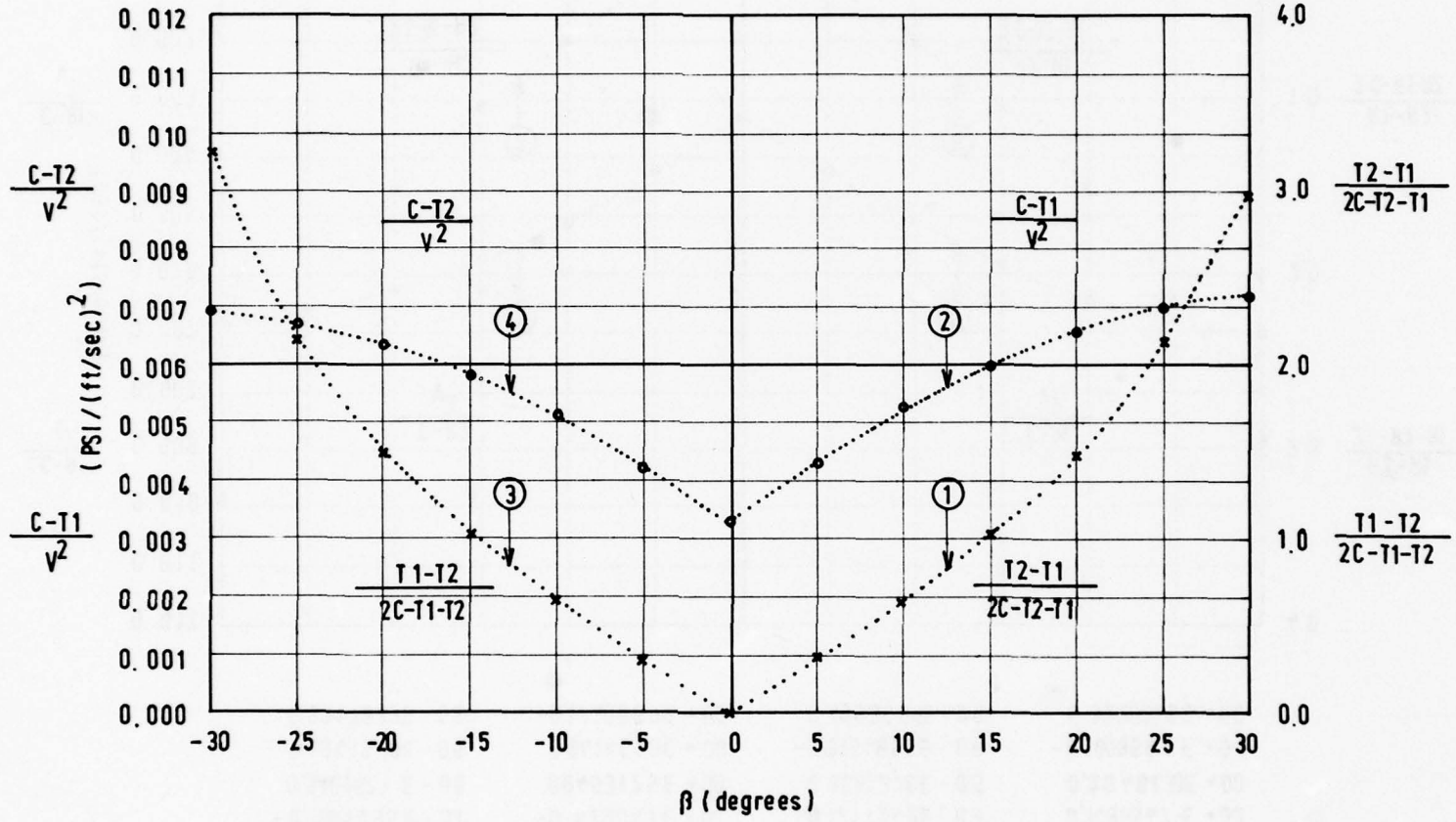


Figure 39 -Pre Calibration of Tube 23 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3198206E-02	0.9521484E-01	0.3198206E-02	-0.1052246E+00
-0.2235770E-03	-0.1543750E+02	0.2454519E-03	0.1589844E+02
0.1505017E-05	-0.7617188E+00	-0.4943460E-05	-0.8789063E+00
0.3869645E-06	0.1875000E+01	0.4819594E-07	-0.7890625E+00
0.7901690E-08	-0.3510742E+00	-0.4802132E-09	0.1394043E+00

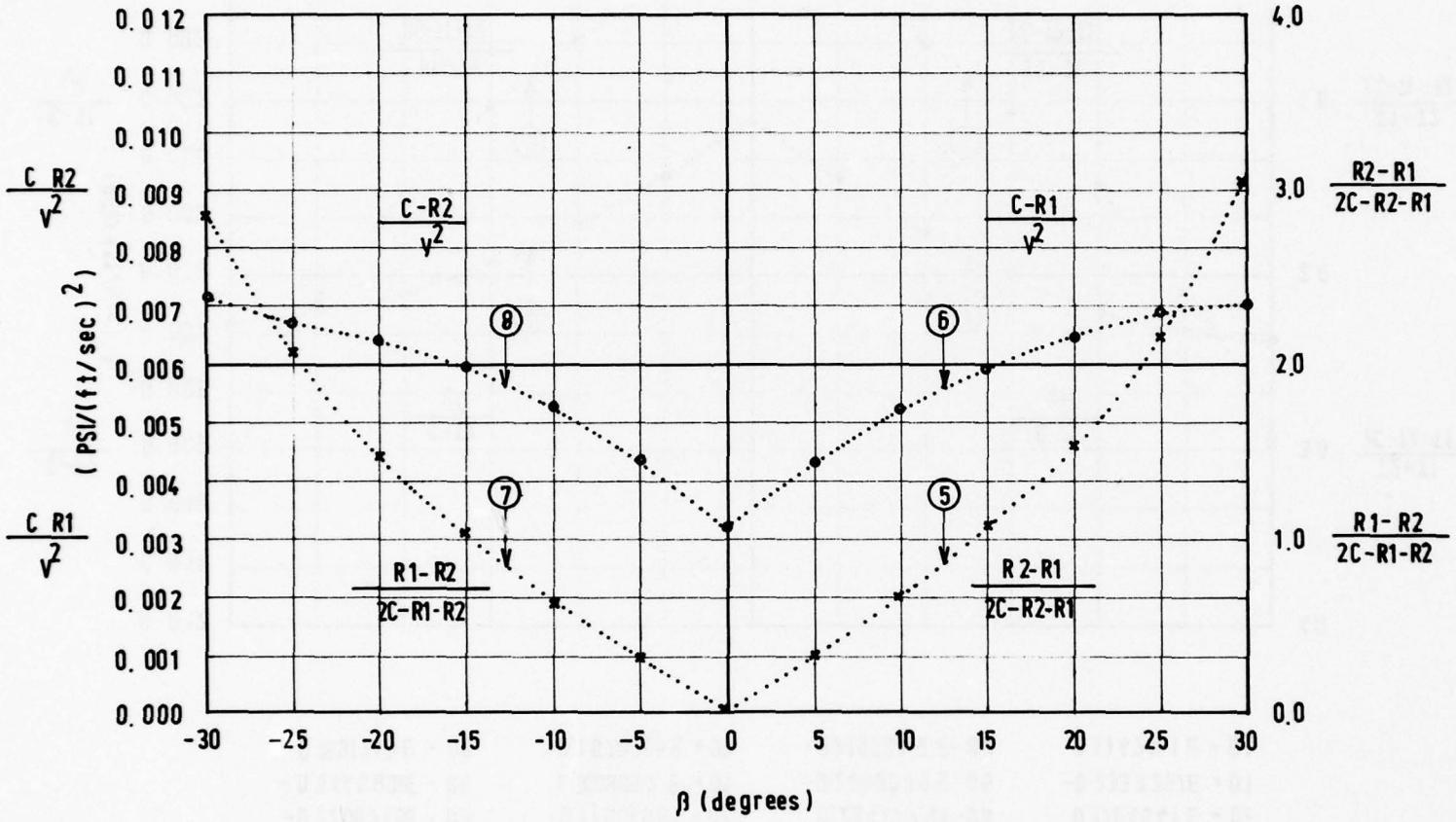


Figure 40 -Pre Calibration of Tube 23 in Vertical-Radial Plane

④ 0.3271163E - 02	③ 0.2570801E + 00	② 0.3292561E-02	① -0.3183594E + 00
-0.2200715E - 03	-0.1750488E + 02	0.2211779E-03	0.1704541E + 02
-0.3445894E - 05	0.3008057E + 01	-0.2492219E-05	-0.2333252E + 01
-0.1891749E - 09	-0.1572266E + 00	-0.2197339E-07	0.1147461E - 01

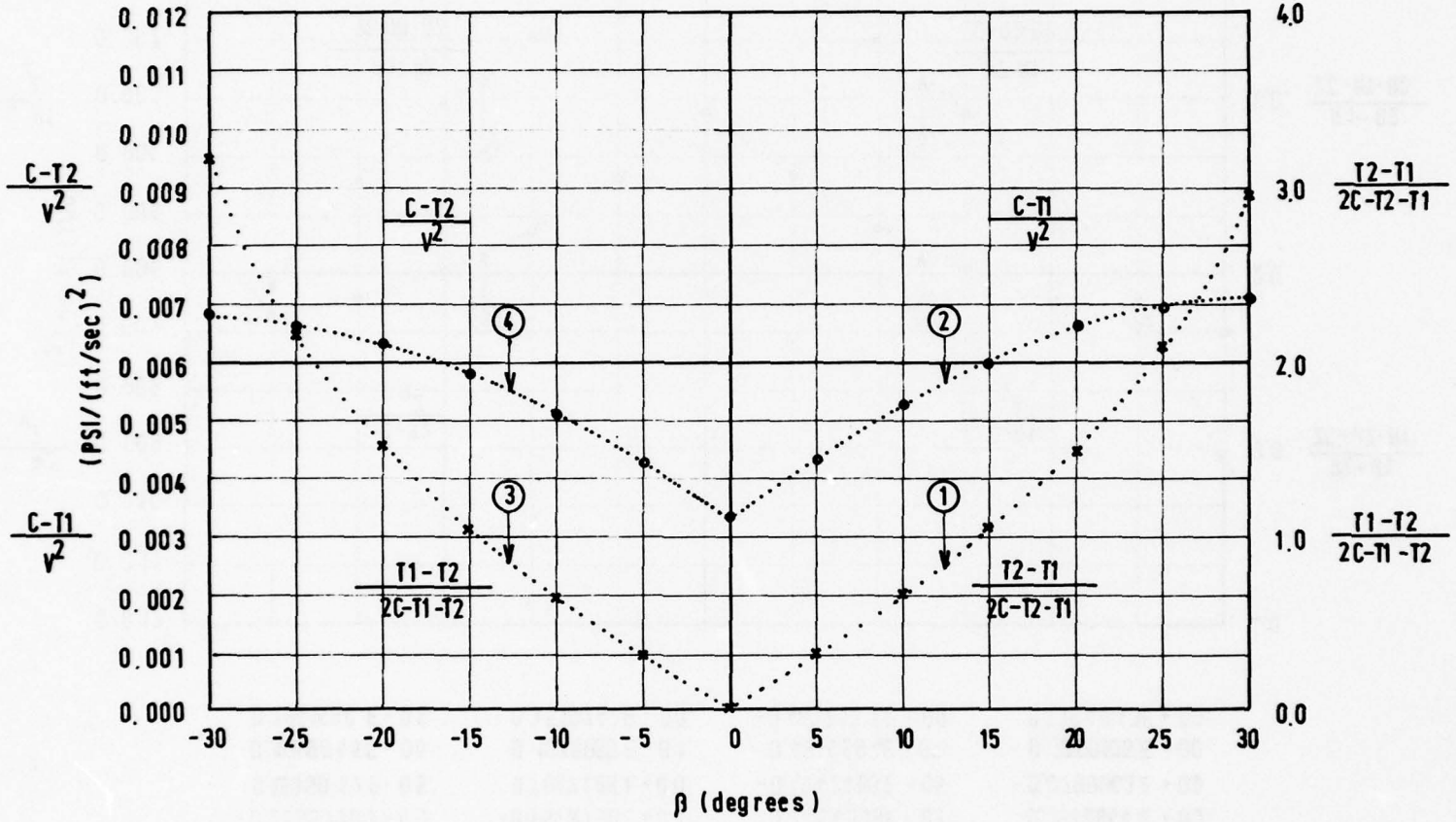


Figure 41 -Pre Calibration of Tube 24 in Horizontal-Tangential Plane

⑧ 0.3287852E-02	⑦ 0.3100586E + 00	⑥ 0.3292561E-02	⑤ -0.2961426E + 00
-0.2193712 E-03	-0.1801343E + 02	0.2222210 E-03	0.1687573E + 02
-0.3106892 E-05	0.3104004E + 01	-0.3296882 E-05	-0.2690186E + 01
-0.1891749 E-09	-0.1740723 E + 00	0.2328306 E-09	0.1225586E + 00

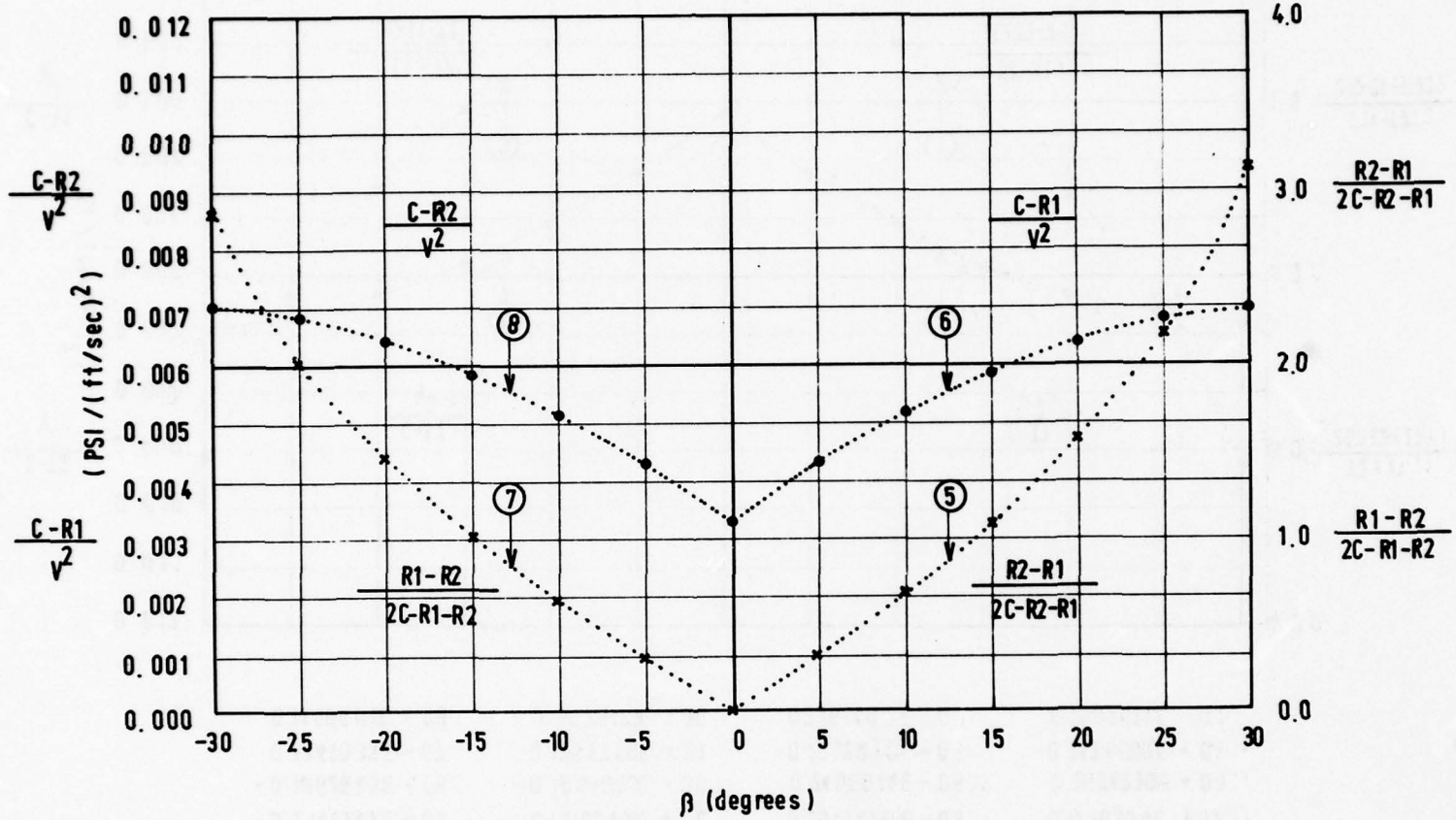


Figure 42 -Pre Calibration of Tube 24 in Vertical-Radial Plane

④	③	②	①
0.3196180E - 02	0.1879883E + 00	0.3198266 E - 02	-0.2199707E + 00
-0.2148747E - 03	- 0.1510547E + 02	0.2047420E - 03	0.1718359E + 02
-0.1862645E - 05	- 0.7851563E + 00	0.2495944E - 06	-0.2574219E + 01
0.7241033E - 07	0.1761719E + 01	-0.2048910E - 06	- 0.3125000E - 01
0.1149601E - 08	- 0.3076172E + 00	0336149 2E - 08	0.2807617E - 01

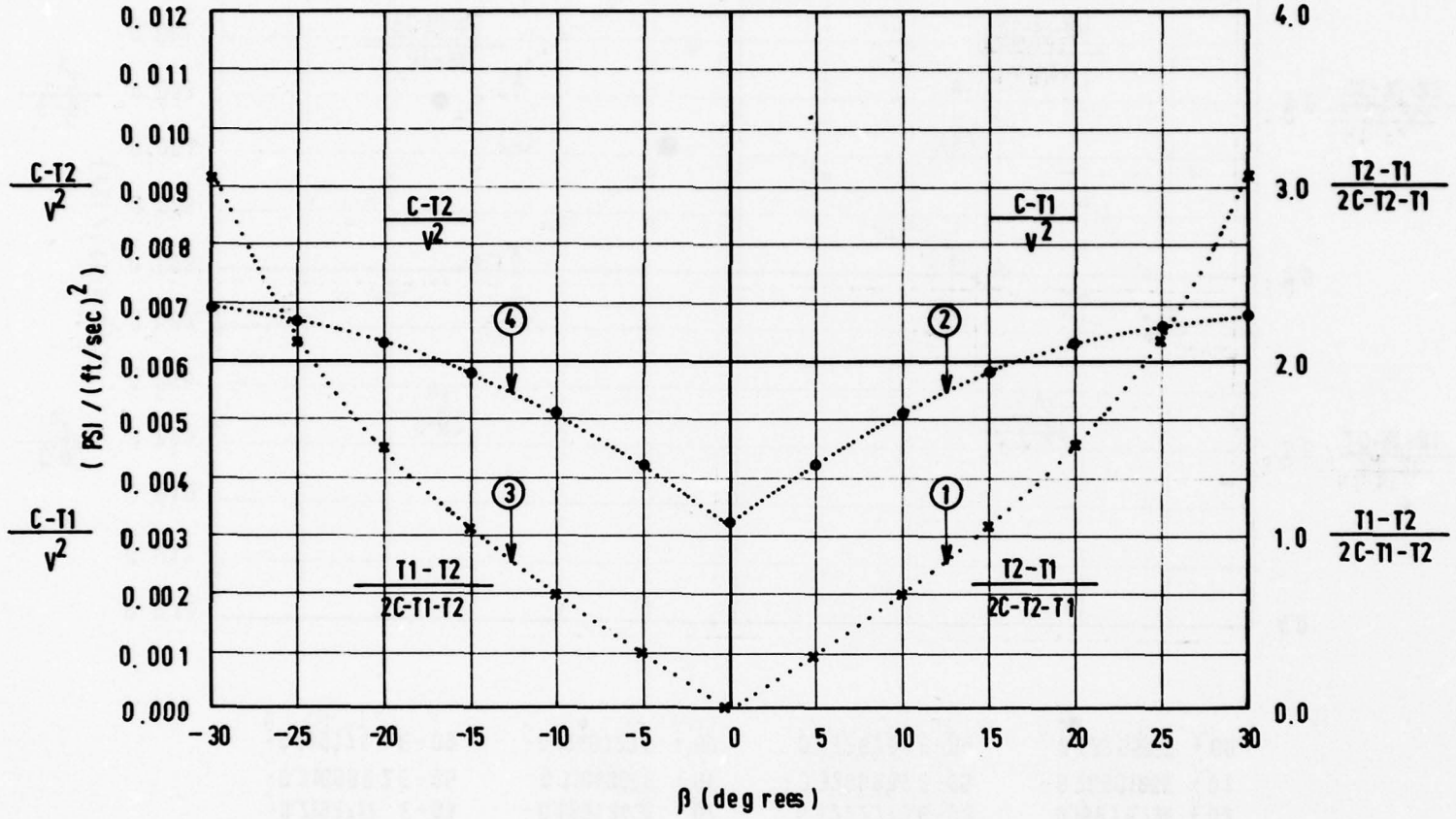


Figure 43 -Pre Calibration of Tube 26 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3195465E - 02	0.3242188E +00	0.3197193E - 02	-0.3374023E +00
-0.1791120E - 03	-0.1749219E +02	0.1958013E - 03	0.1567578E +02
0.2074987E - 05	0.2273437E +01	0.2626330E - 05	0.1953125E - 01
0.2398156E - 06	0.3125000E +00	-0.3394671E - 06	-0.1417969E +01
0.3245077E - 08	-0.7177734E - 01	0.6097252E - 08	0.2551270E +00

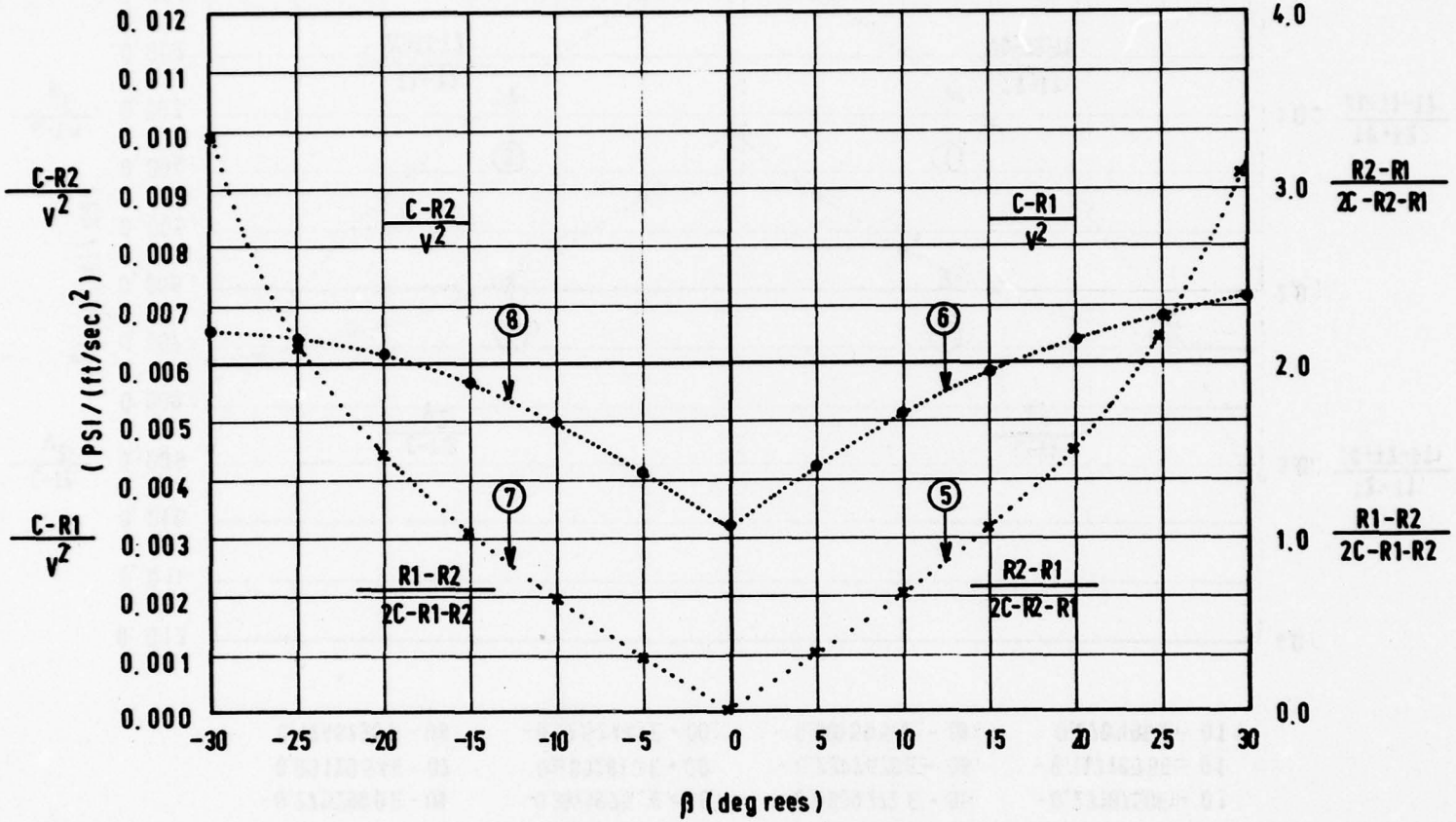


Figure 44 -Pre Calibration of Tube 26 in Vertical-Radial Plane

④	③	②	①
0.3293157E-02	0.8447266E-01	0.3288984E-02	-0.1376953E+00
-0.2423525E-03	-0.1555078E+02	0.2114177E-03	0.1739062E+02
-0.2752990E-05	0.3671875 E+00	0.9909272E-06	-0.2718750E+01
0.8312054E-07	0.8632813E+00	-0.2777670E-06	-0.1171875E-01
0.1746230E-09	-0.1252441E+00	0.5005859E-08	0.2709961E-01

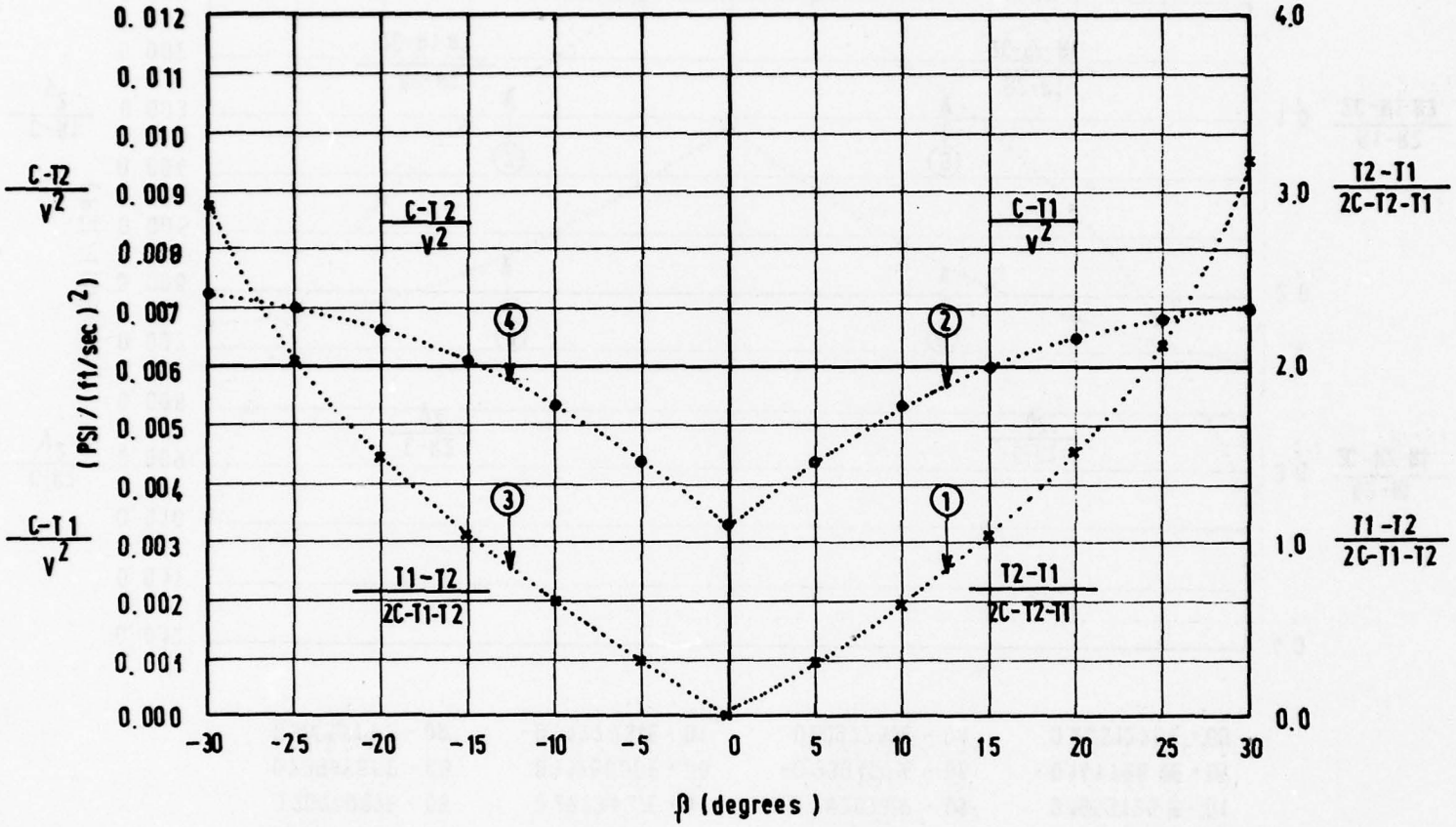


Figure 45 -Pre Calibration of Tube 27 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3401041E - 02	0.1303711E + 00	0.3390968E - 02	-0.1484375E + 00
-0.2375245E - 03	-0.1514844E + 02	0.1714826E - 03	0.1690625E + 02
- 0.3516674E - 05	-0.1261719E + 01	0.5420297E - 05	- 0.1898438E + 01
0.2887100E - 07	0.2078125E + 01	- 0.4477333E - 06	-0.5195313E + 00
0.1193257E - 08	- 0.3857422E + 00	0.7130438E - 08	0.1174316E + 00

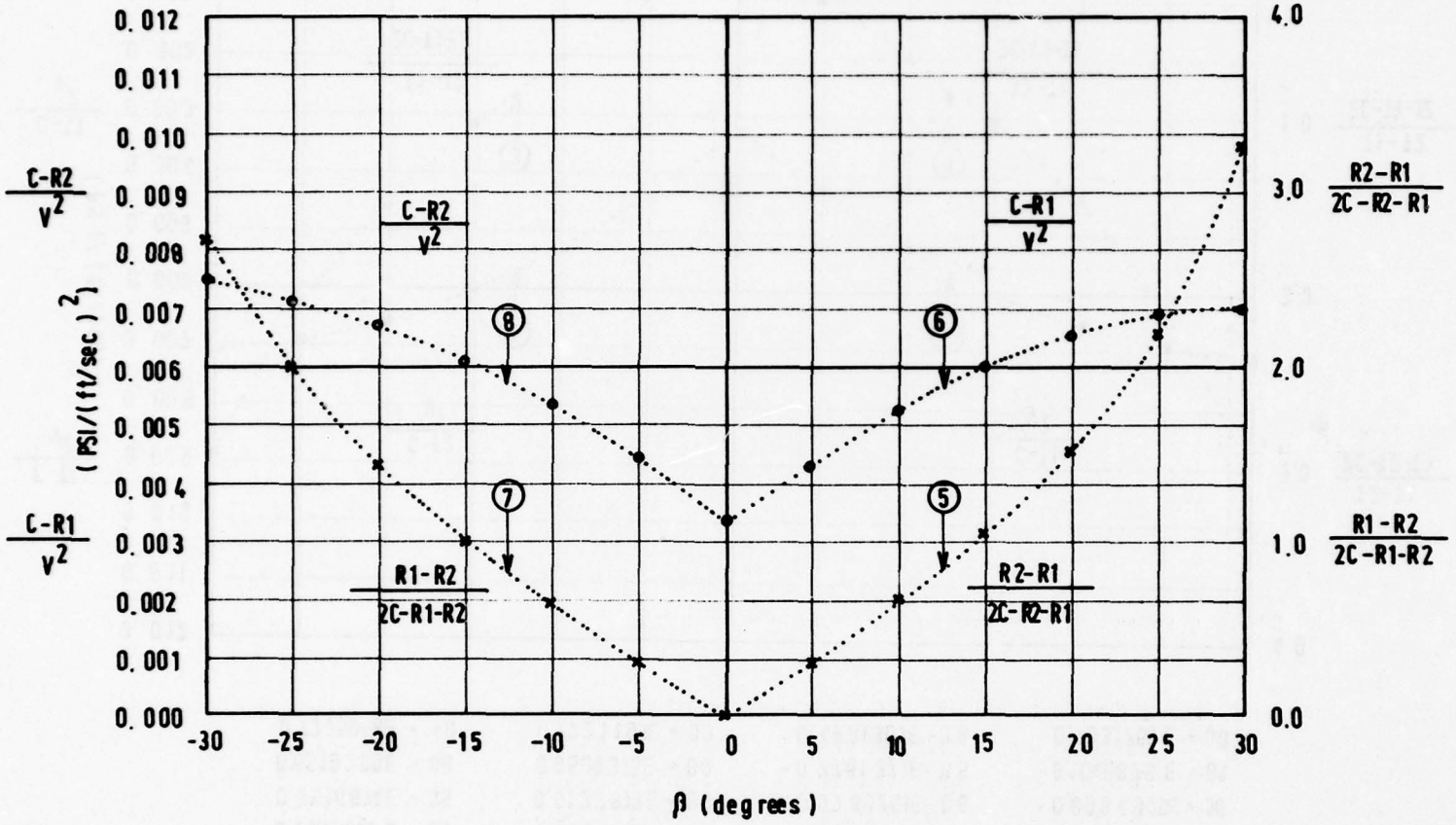


Figure 46 -Pre Calibration of Tube 27 in Vertical-Radial Plane

④	③	②	①
0.3302276E - 02	0.2500000 E + 00	0.3203213E-02	-0.2404785E + 00
-0.2360344 E - 03	-0.1598437E + 02	0.2170801E-03	0.1667969E + 02
-0.3516674E - 05	0.6132813E + 00	0.9760261E-06	-0.8984375E + 00
0.6519258E - 08	0.9609375E + 00	-0.2761371E-06	-0.1046875 E + 01
0.7275958E - 10	-0.1721191E + 00	0.4991307E-08	0.2031250 E + 00

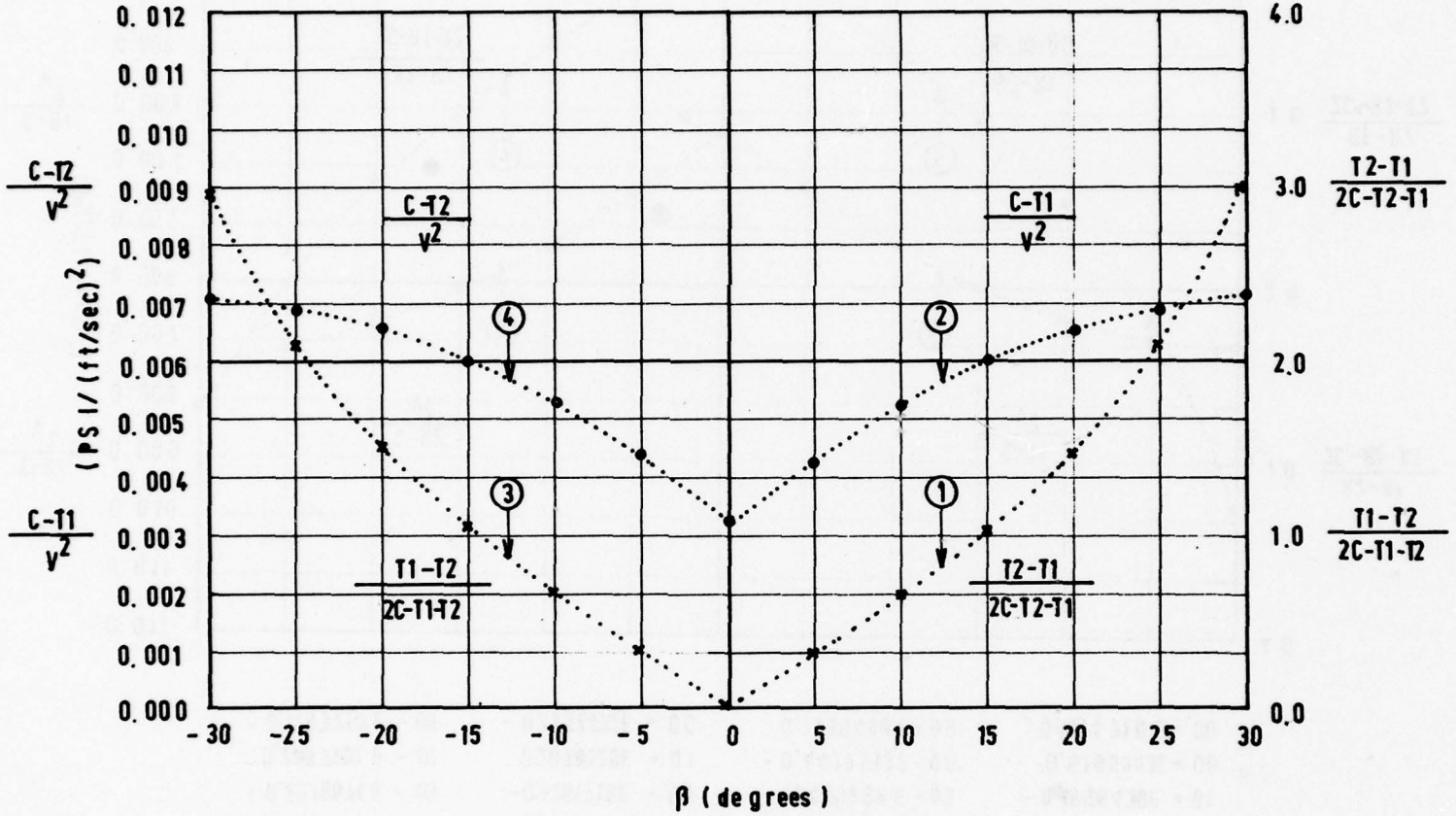


Figure 47 -Pre Calibration of Tube 28 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3300309E-02	0.1076660E+00	0.3299057E-02	-0.1003418E+00
-0.1952052E-03	-0.1561719E+02	0.1968741E-03	0.1575391E+02
0.1884997E-05	-0.1250000E+00	0.1780689E-05	-0.3710938E+00
0.2440065E-06	0.1292969E+01	-0.2665911E-06	-0.1105469E+01
0.3274181E-08	-0.2087402E+00	0.4394678E-08	0.1940918E+00

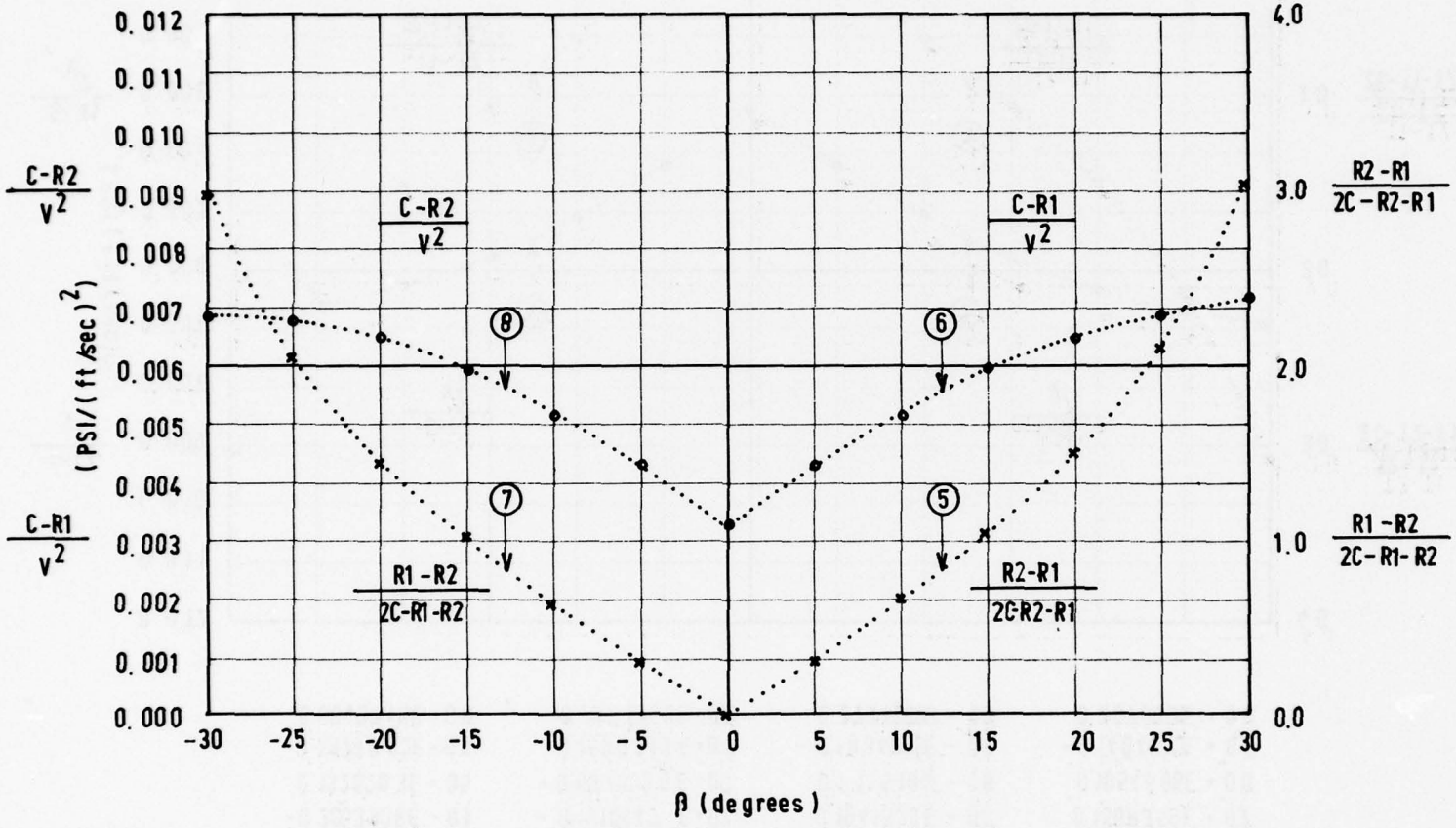


Figure 48 -Pre Calibration of Tube 28 in Vertical-Radial Plane

④	③	②	①
0.3198743E-02	0.9570313E-01	0.3205657E-02	-0.1074219E+00
-0.2003908E-03	-0.1510547 E+02	0.1941323E-03	0.1568359E+02
0.1326203E-05	-0.6875000E+00	0.7115304E-06	0.1054688E+00
0.2828892E-06	0.1699219E+01	-0.1834705E-06	-0.1484375E+01
0.5049515E-08	-0.2983398E+00	0.2721208E-08	0.2670898E+00

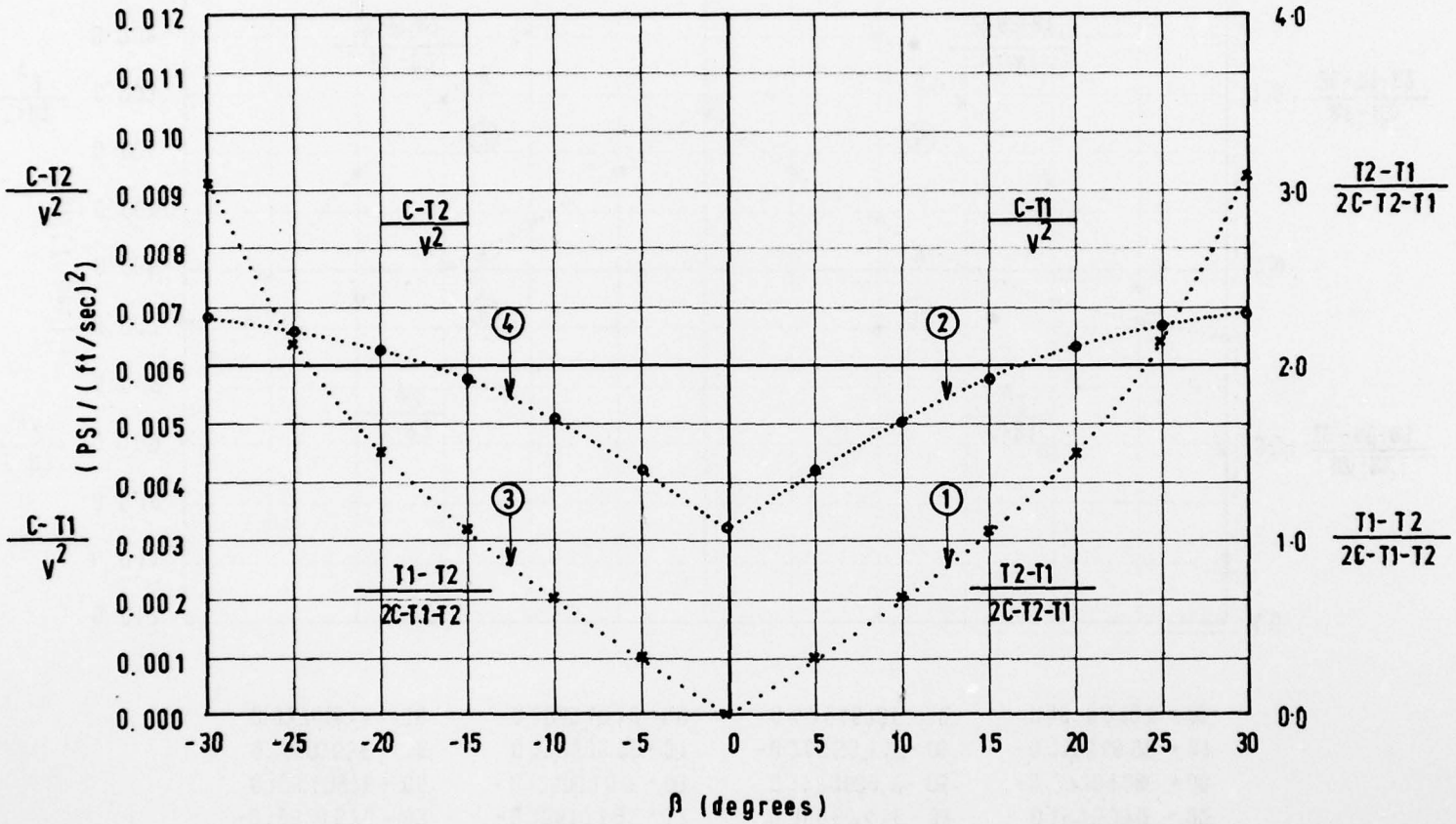


Figure 49 -Pre Calibration of Tube 29 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3103316E-02	0.9667969E-01	0.3102124E-02	-0.1027832E+00
-0.2010465E-03	-0.1605078E+02	0.2361536E-03	0.1483984E+02
-0.2346933E-06	0.5742188E+00	-0.3531575E-05	0.7617188E+00
0.8987263E-07	0.1101562E+01	-0.2793968E-08	-0.1621094E+01
0.4511094E-09	-0.1997070E+00	0.5820766E-10	0.2697754E+00

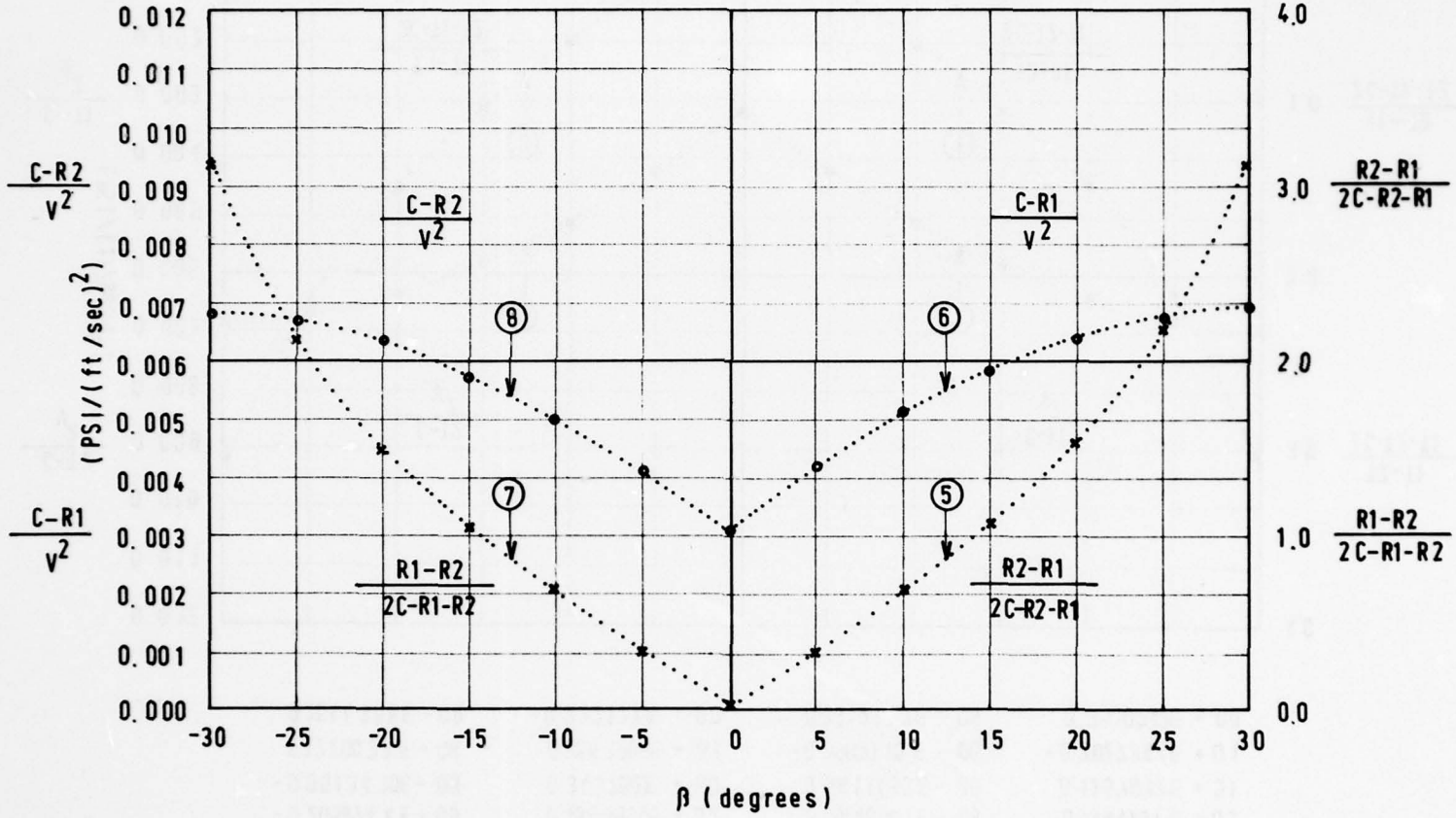


Figure 50 - Pre Calibration of Tube 29 in Vertical-Radial Plane

④	③	②	①
0.3199875E-02	0.6005859E-01	0.3200531E-02	-0.2124023E-01
-0.2058744E-03	-0.1583594E+02	0.2014041E-03	0.1491797E+02
-0.5513430E-06	0.3437500E+00	0.5811453E-06	0.1257812E+01
0.1220033E-06	0.1253906E+01	-0.2000015E-06	-0.2027344E+01
0.1644366E-08	-0.2321777E+00	0.3317837E-08	0.3510742E+00

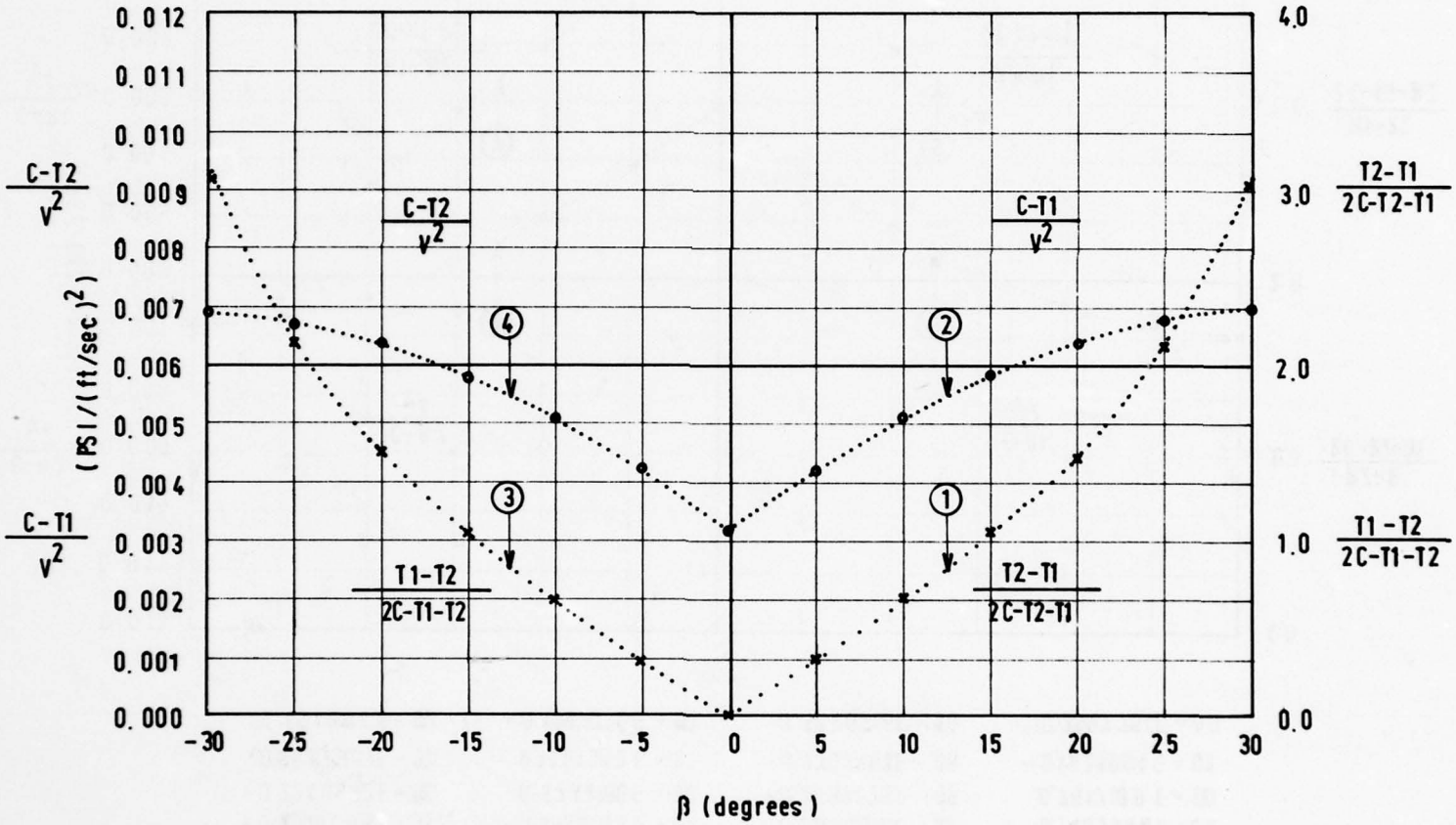


Figure 51 -Pre Calibration of Tube 30 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3196239E - 02	0.5754395E + 00	0.3192484E - 02	-0.5217285E + 00
-0.1304150E - 03	-0.1987109E + 02	0.2166033E - 03	0.1643359E + 02
0.8862466E - 05	0.5562500E + 01	-0.1013279E - 05	-0.2437500E + 01
0.5532056E - 06	-0.1281250E + 01	-0.1359731E - 06	0.3242188E + 00
0.8105417E - 08	0.1652832E + 00	0.2270099E - 08	-0.6298828E - 01

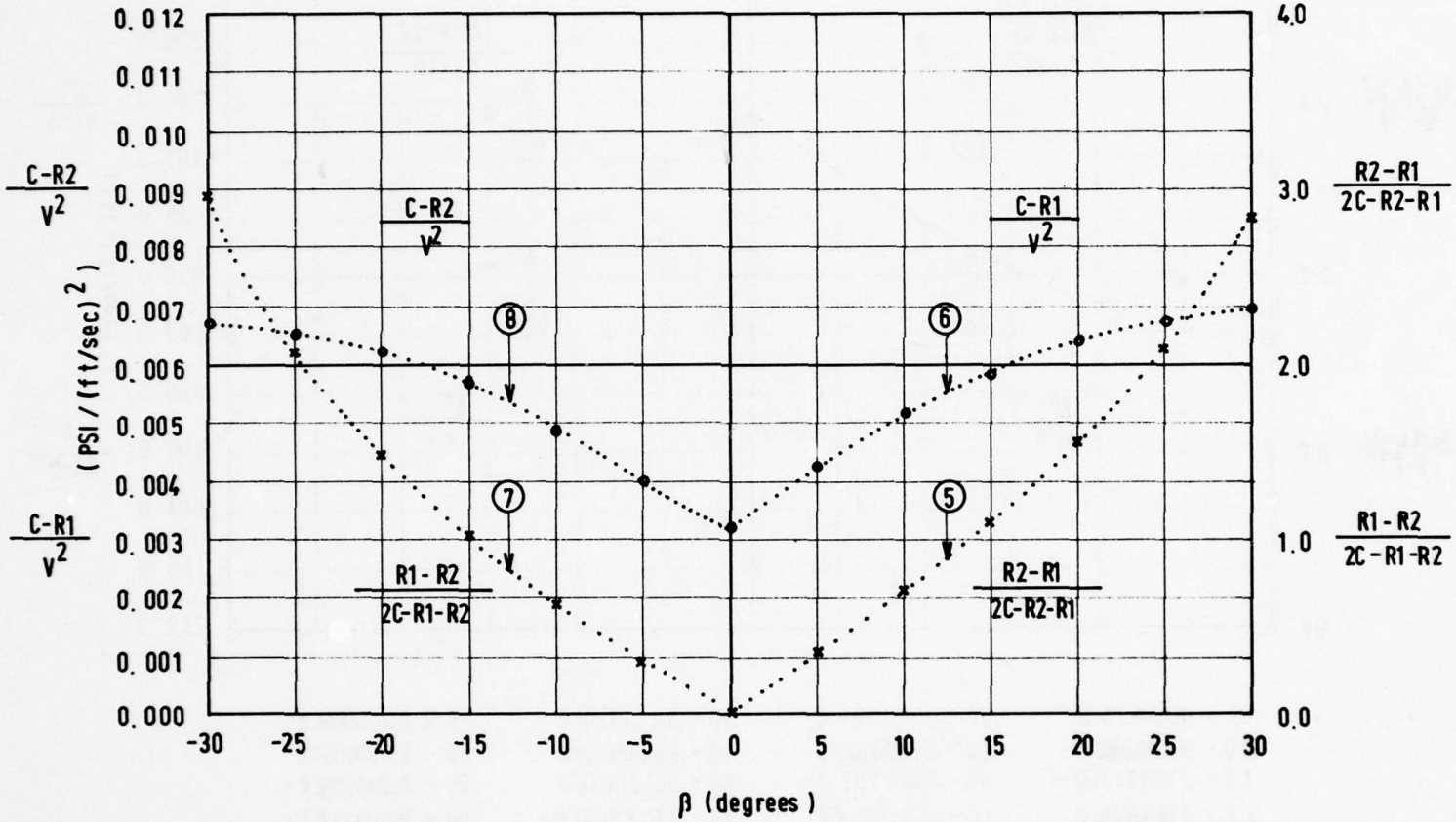


Figure 52 -Pre Calibration of Tube 30 in Vertical-Radial Plane

④	③	②	①
0.3196776E - 02	0.6787109E - 01	0.3198028E - 02	-0.7812500E - 01
-0.2104044E - 03	-0.1574219E + 02	0.2156496E - 03	0.1650594E + 02
-0.8456409E - 06	0.3320313E + 00	-0.2644956E - 05	-0.1722656E + 01
0.1504086E - 06	0.1039063E + 01	0.1303852E - 07	-0.2890625E + 00
0.2852175E - 08	-0.1826172E + 00	-0.4947651E - 09	0.4248047E - 01

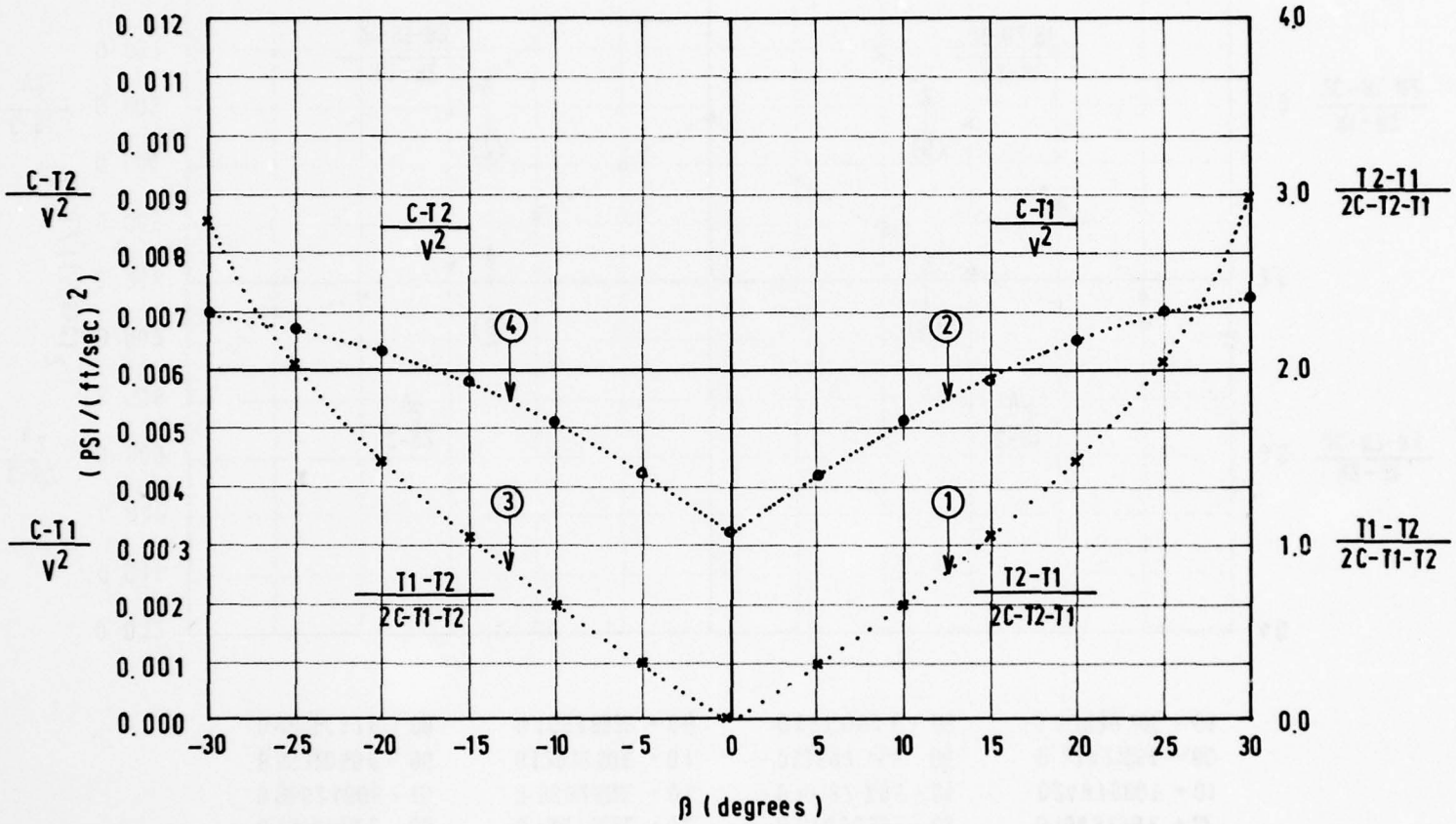


Figure 53 -Pre Calibration of Tube 31 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3 2055 38E - 02	0.2319336E - 01	0.3203154E - 02	- 0.55908 20 E - 01
-0.2050996 E - 03	- 0.1598047 E + 02	0.2273917 E - 03	0.1583 203 E + 02
- 0.2242625E - 05	0.1070312 E + 01	-0.134 1105 E - 05	- 0.1187 500E + 01
- 0.2328 306E - 0 7	0.6015625E + 00	- 0.1587905 E - 06	- 0.4335938 E + 00
-0.1149601 E - 0 8	-0.1115723E + 00	0.3390596 E - 08	0.6958008 E - 01

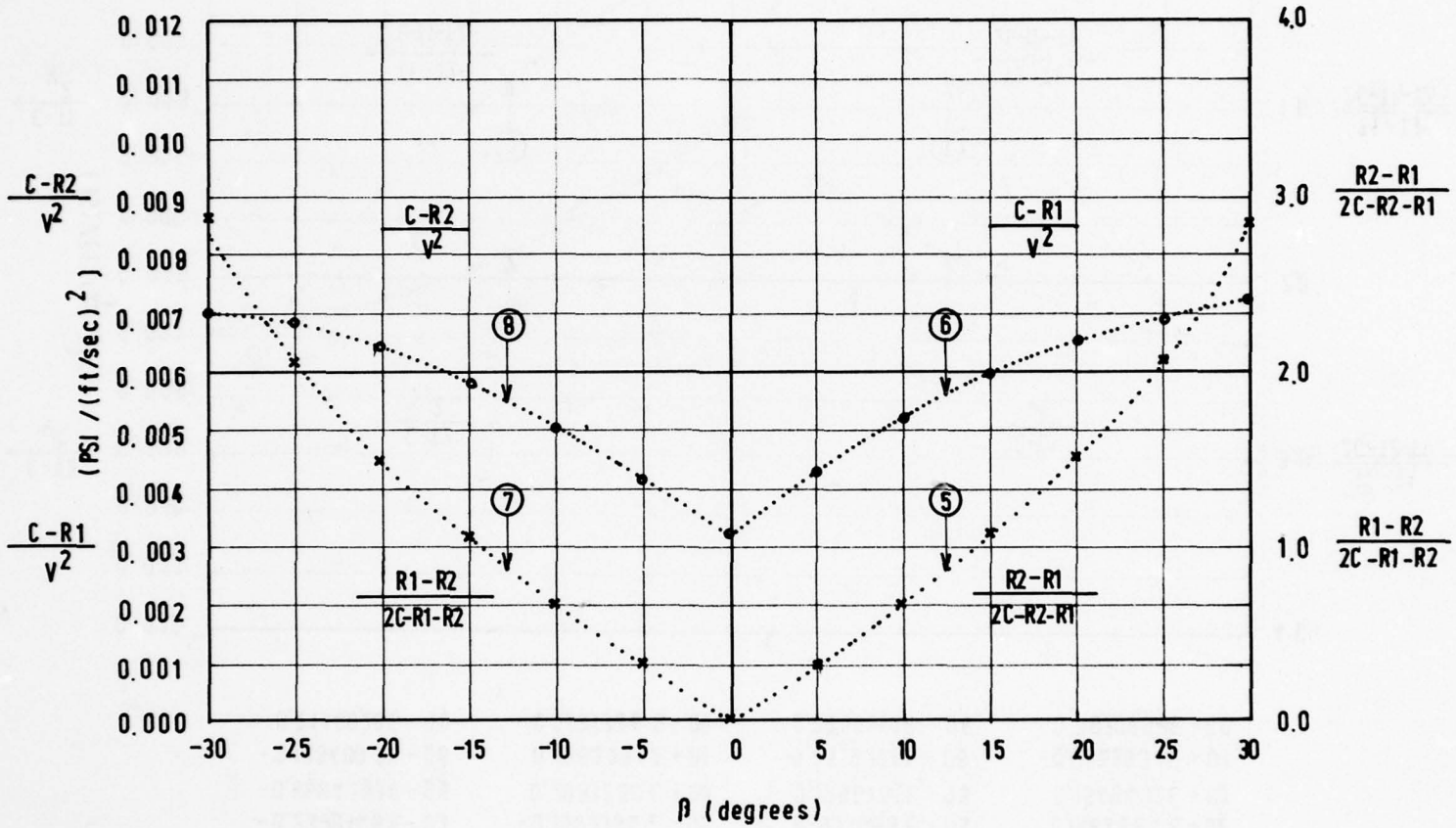


Figure 54 -Pre Calibration of Tube 31 in Vertical-Radial Plane

④	③	②	①
0.3207386E-02	0.8984375E-01	0.3204465E-02	-0.5786133E-01
-0.2390146E-03	-0.1592188 E+02	0.1921058 E-03	0.1483984 E+02
-0.5684793E-05	0.2031250 E+00	0.1996756E-05	0.1648437 E+01
-0.1234002E-06	0.1363281 E+01	-0.2519228E-06	-0.2269531 E+01
-0.2110028E-08	-0.2531738 E+00	0.3856258E-08	0.3920898E+00

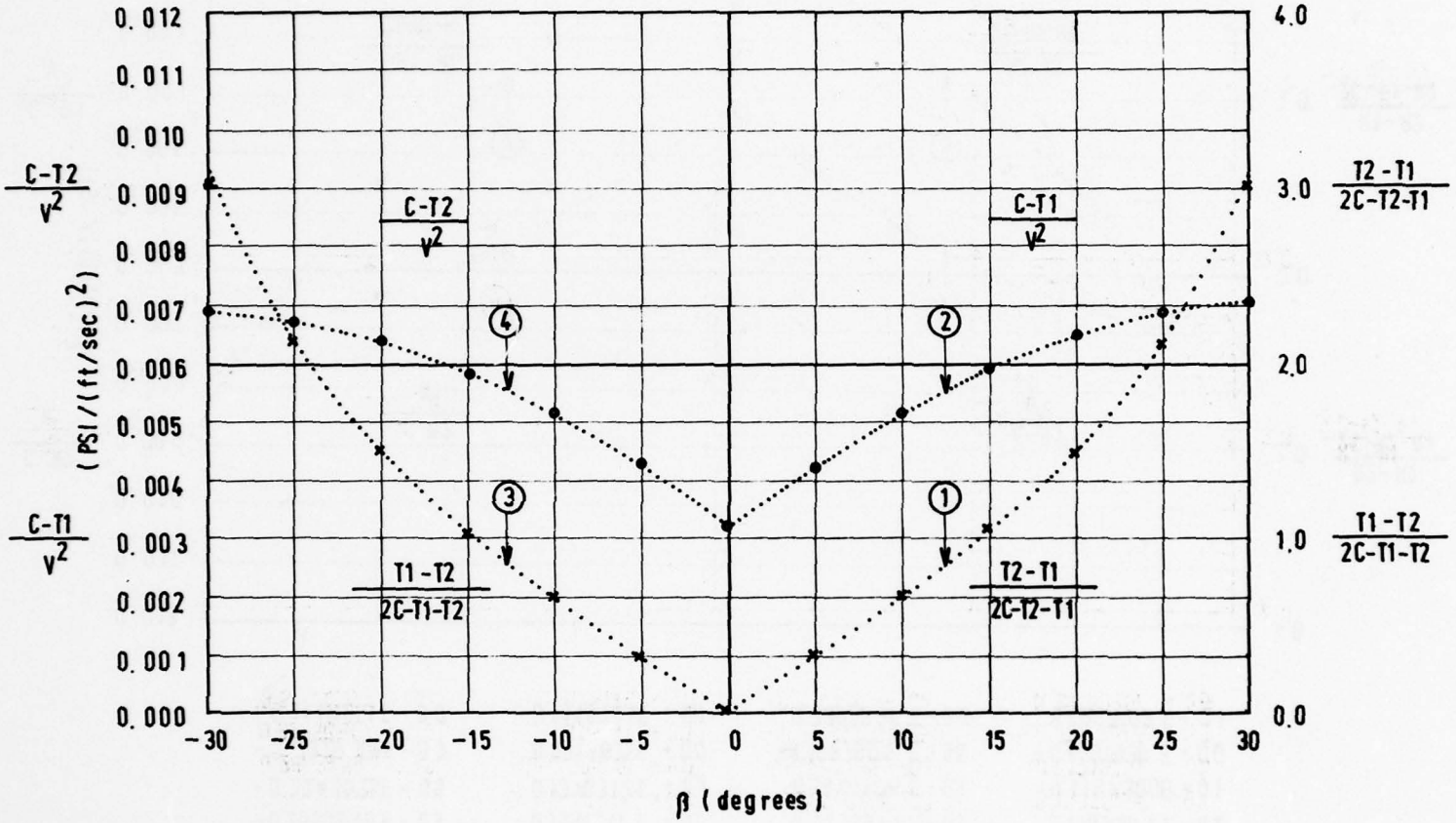


Figure 55 -Pre Calibration of Tube 32 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3188372E - 02	0.1628418E + 00	0.3198564E-02	-0.2158203 E + 00
- 0.1853108E - 03	- 0.1645703E + 02	0.2012253E-03	0.1537500E + 02
0.2808869E - 05	0.6250000E + 00	0.4820105E-06	0.6171875E + 00
0.3355090E - 06	0.1183594E + 01	-0.1834705E-06	- 0.1757813E + 01
0.5544280E - 08	- 0.2182617E + 00	0.2721208E-08	0.3186035E + 00

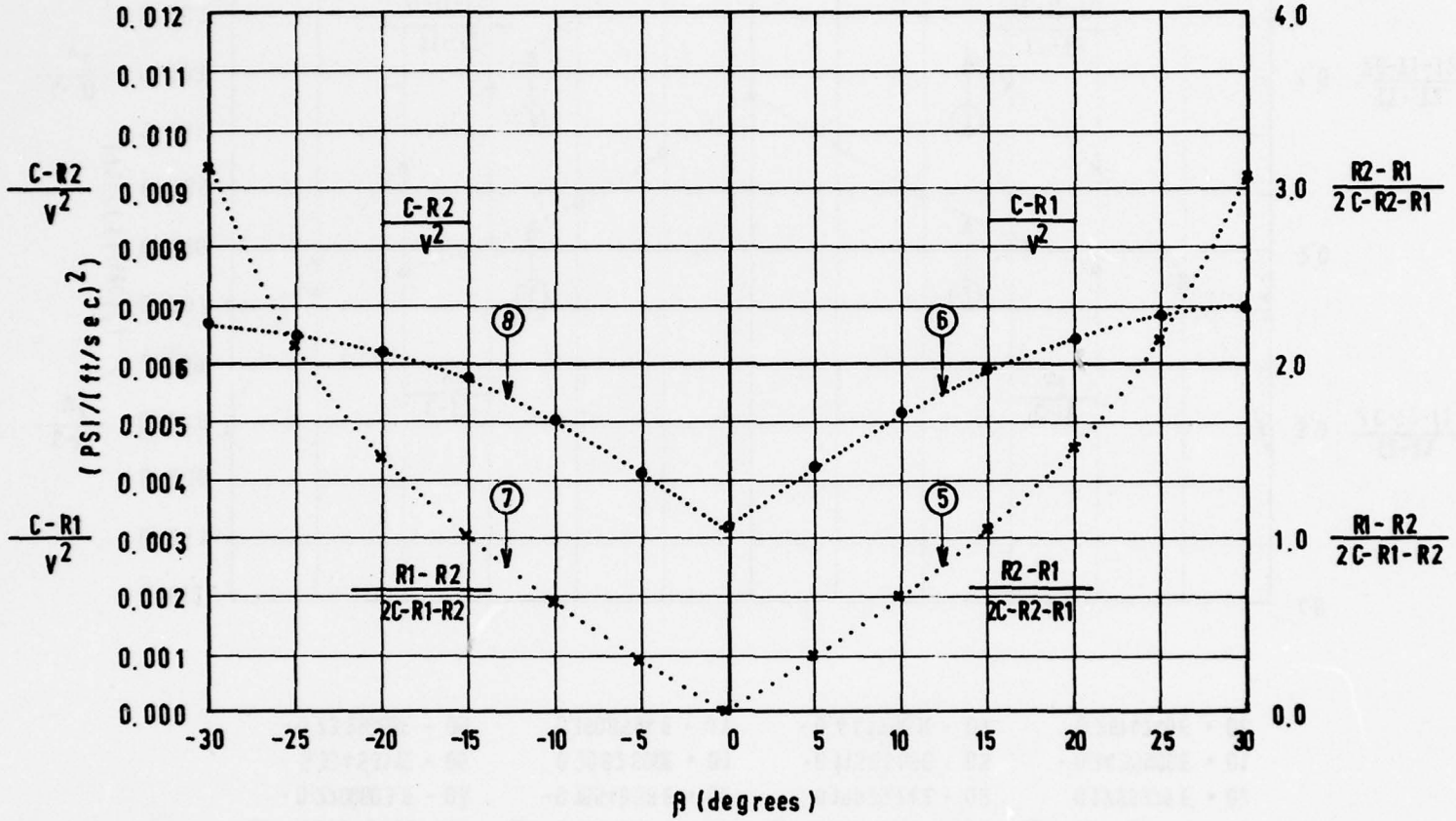


Figure 56 - Pre Calibration of Tube 32 in Vertical-Radial Plane

④ 0.3297329E - 02	③ 0.1772461E + 00	② 0.3290117E - 02	① -0.1743164E + 00
-0.2200603 E - 03	-0.1654858 E + 02	0.1907274 E - 03	0.1785376 E + 02
-0.3345311E - 05	0.2062500E + 01	-0.1158565E - 05	-0.3430908E + 01
-0.2328306E - 09	0.3808594 E - 01	-0.4417961E - 07	0.2614746 E + 00

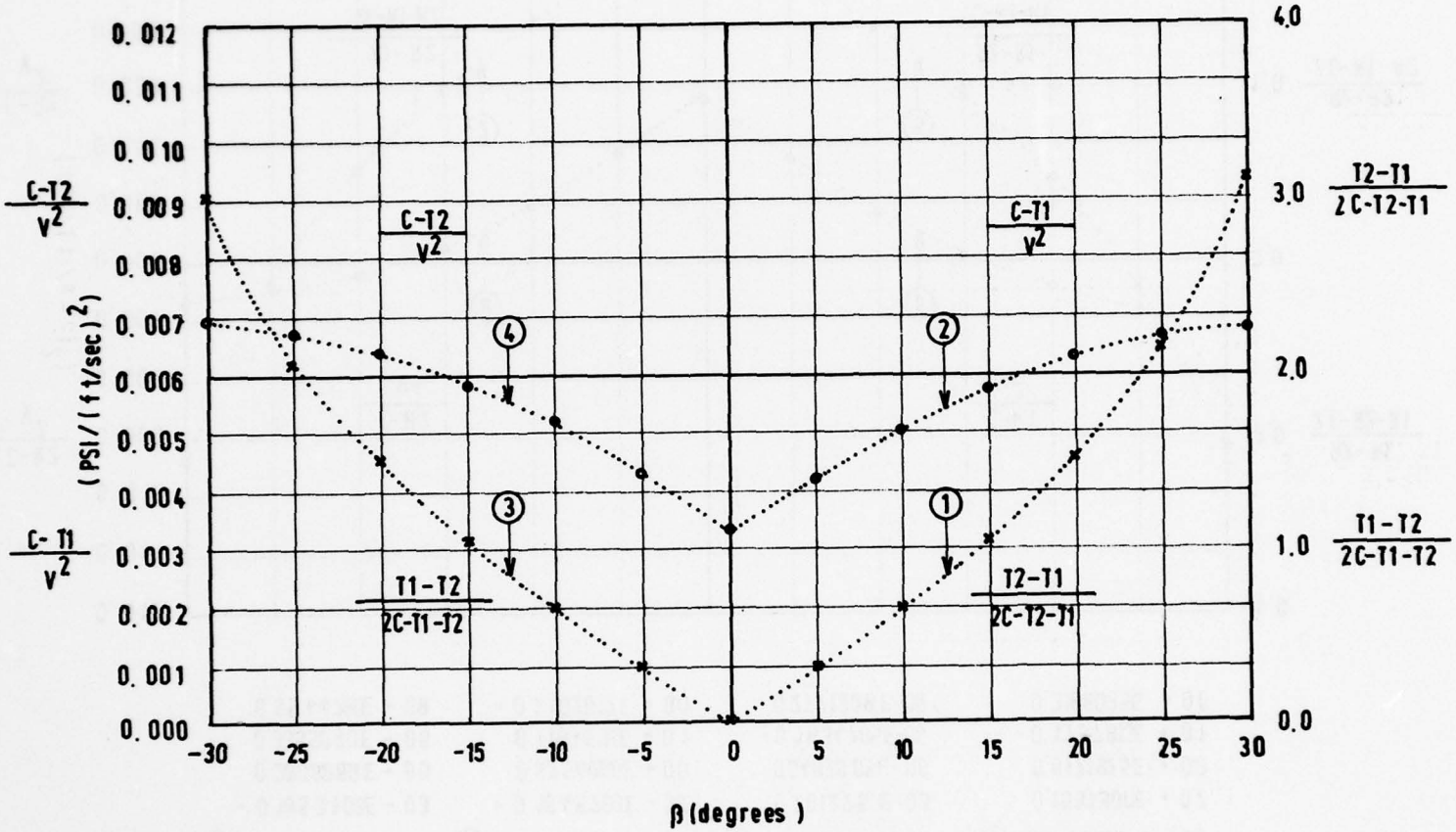


Figure 57 - Pre Calibration of Tube 33 in Horizontal-Tangential Plane

⑧ 0.3178239E - 02	⑦ 0.3225098E + 00	⑥ 0.3187895 E - 02	⑤ -0.3522949E + 00
- 0.2028644E - 03	-0.1793188 E + 02	0.2282932 E - 03	0.1690234 E + 02
- 0.1683831 E - 05	0.3189941 E + 01	-0.4056841E - 05	- 0.2498779 E + 01
0.4416506E - 07	- 0.1713867 E + 00	0.2233719 E - 07	0.7983398E - 01

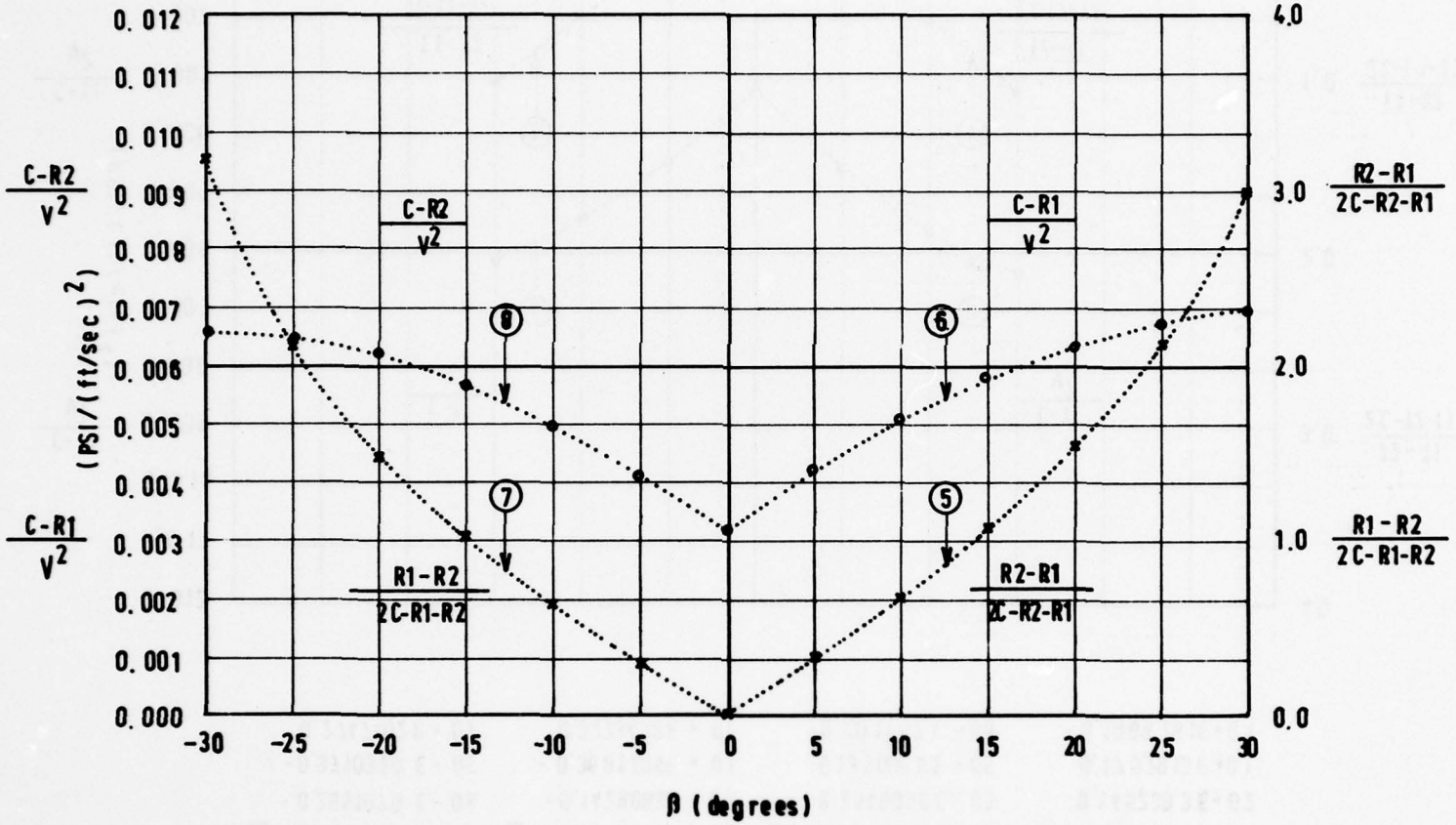


Figure 58 -Pre Calibration of Tube 33 in Vertical-Radial Plane

④	③	②	①
0.3224008E-02	0.6176758E-01	0.3223959E-02	-0.6285095E-01
-0.2551079E-03	-0.1429883E+02	0.2548099E-03	0.1452393E+02
-0.3710389E-05	-0.3691406E+01	0.1356006E-05	0.1757813E+01
0.2747402E-07	0.3273438E+01	-0.3001187E-06	-0.1988281E+01

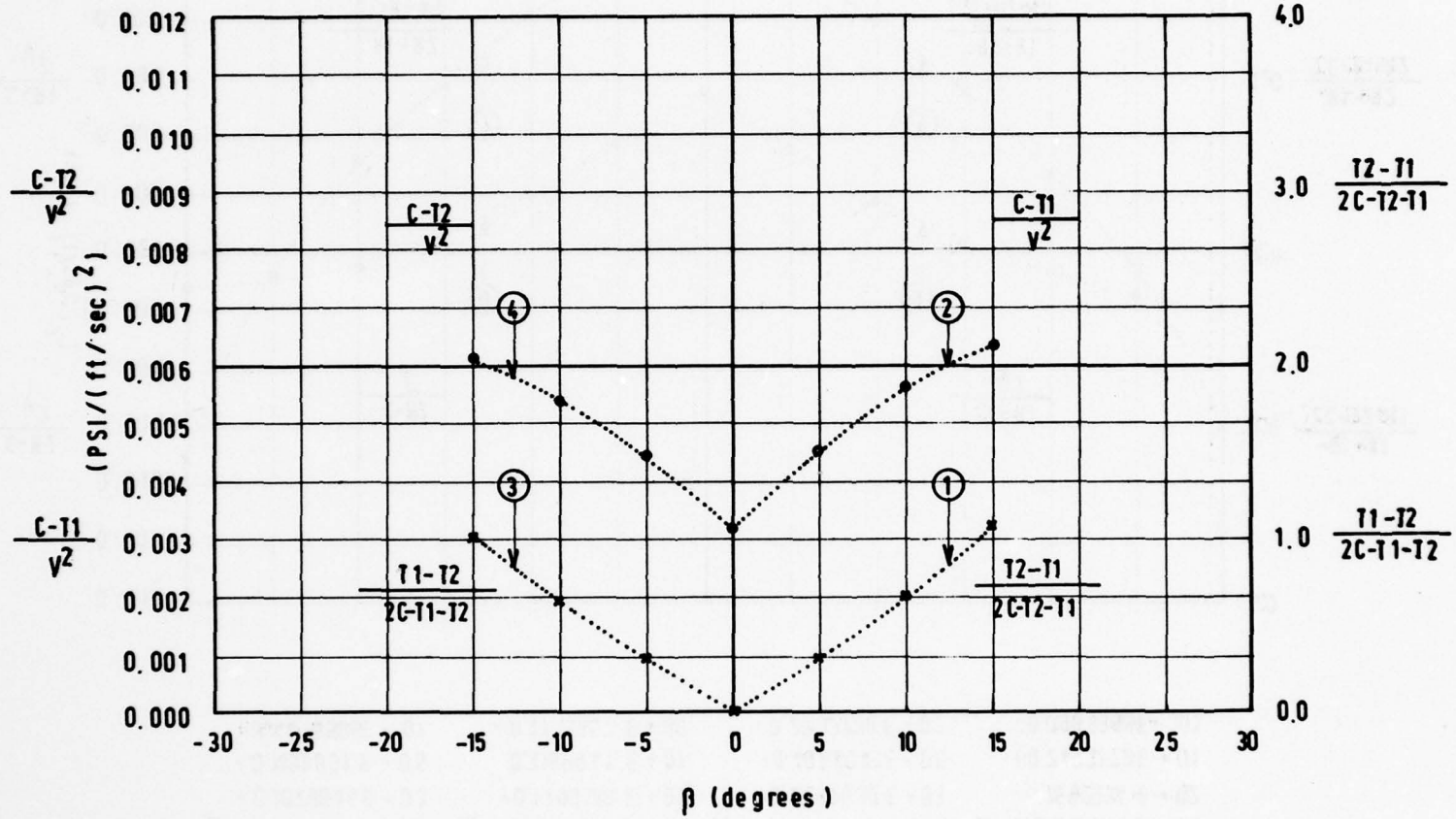


Figure 59 -Post Calibration of Tube 3 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3341012 E - 02	0.2326660E+00	0.3341038E - 02	-0.2176361E+00
- 0.1473427 E - 03	- 0.1889404 E + 02	0.2424717 E - 03	0.1768652 E + 02
0.1100823 E - 04	0.6562500E + 01	- 0.6802380E - 05	- 0.6710938 E + 01
0.5930196 E - 06	- 0.2714844 E + 01	0.1811422 E - 06	0.3316406 E + 01

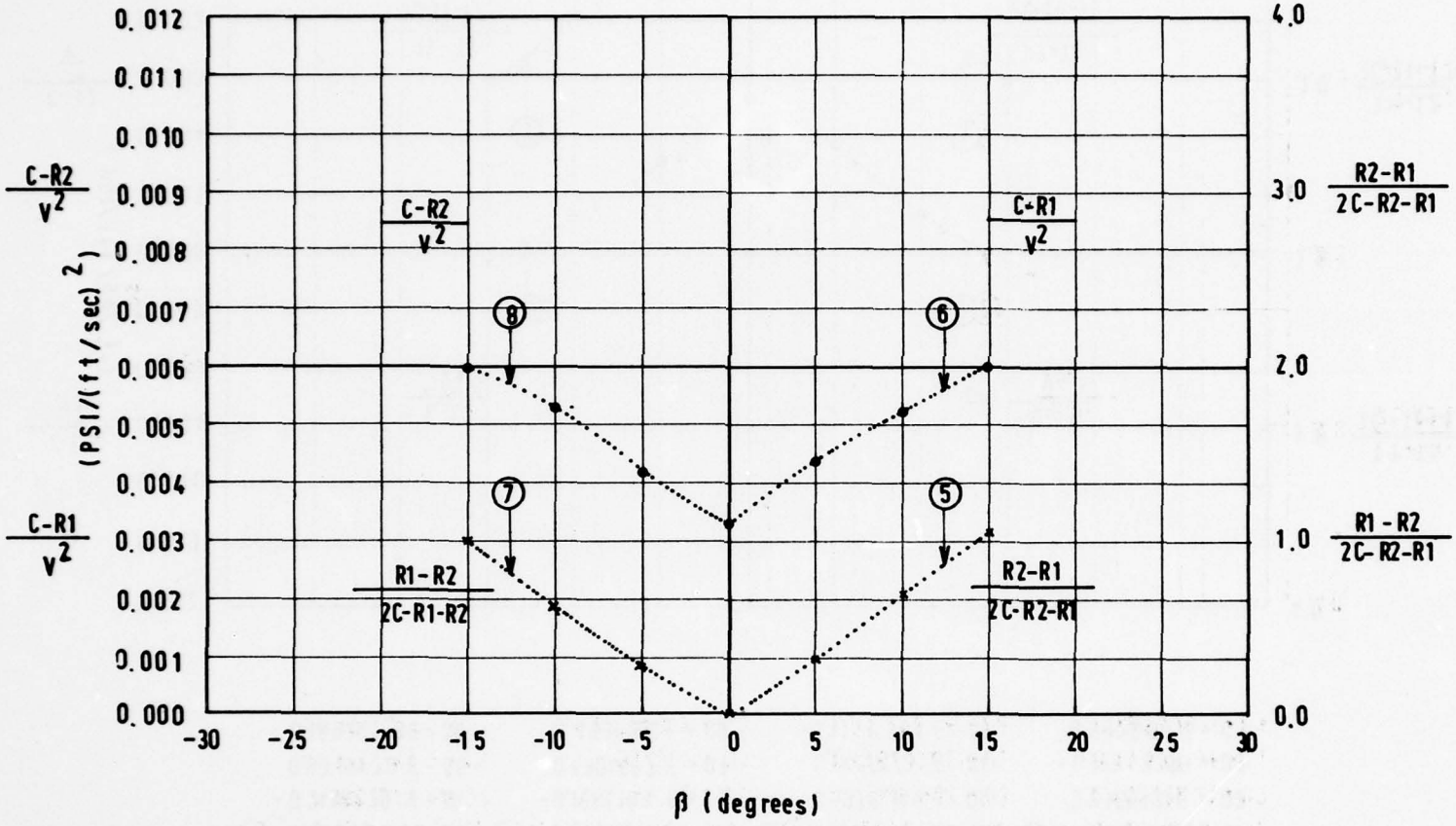


Figure 60 -Post Calibration of Tube 3 in Vertical-Radial Plane

④ 0.3353026 E-02	③ 0.3121948 E+00	② 0.3353000E-02	① -0.4034119E+00
-0.2130270 E-03	-0.1662109 E+02	0.5978346 E-04	0.2168750E+02
0.8717179 E-06	0.1304687 E+01	0.2450123 E-04	-0.1234375E+02
0.1892913E-06	0.4531258 E+00	-0.1111301 E-05	0.5976563E+01

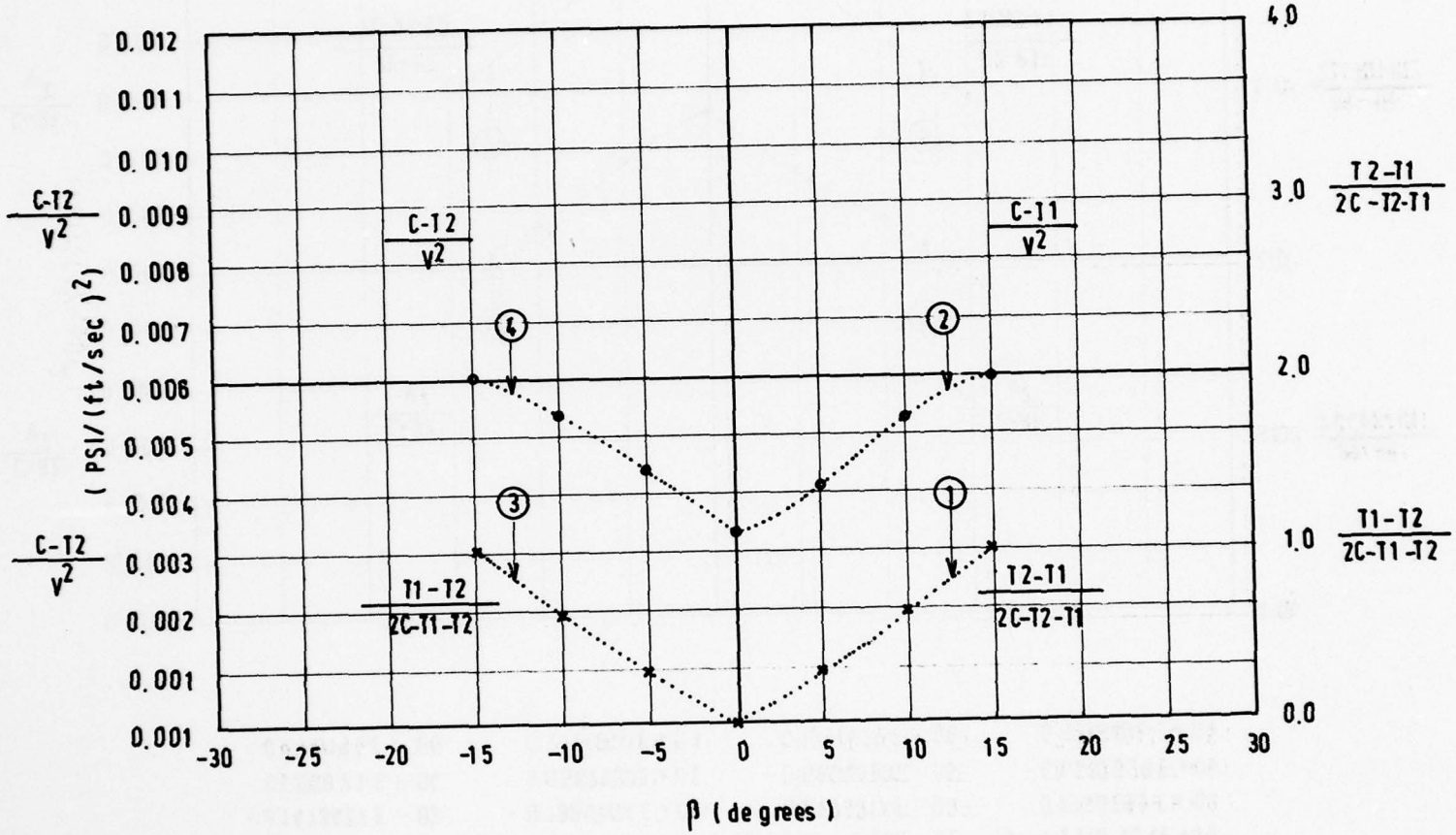


Figure 61 -Post Calibration of Tube 4 in Horizontal-Tangential Plane

⑧ 0.3416065 E-02	⑦ 0.5332184E+00	⑥ 0.3416006E-02	⑤ -0.4484253E+00
-0.1406670 E-03	-0.2048828 E+02	0.2088547E-03	0.1717969 E+02
0.9484589E-05	0.9664062E+01	0.1162291E-05	-0.5675781E+02
0.5071051 E-06	-0.4769531 E+01	-0.1620501E-06	0.3257812 E+01

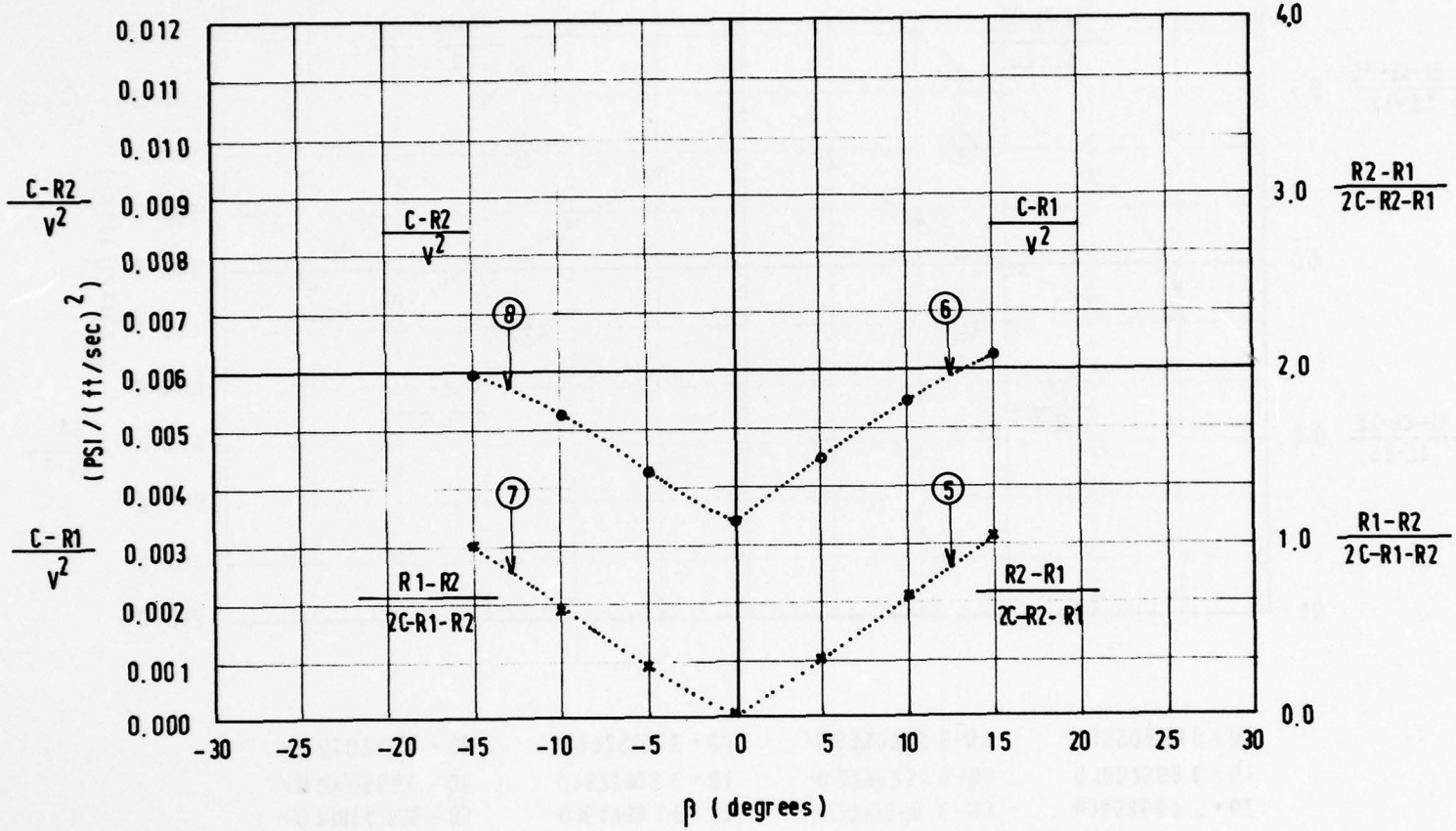


Figure 62 -Post Calibration of Tube 4 in Vertical-Radial Plane

④ 0.3246248 E - 02	③ 0.1148071 E + 00	② 0.3252566E-02	① -0.1012878 E + 00
- 0.2381466E - 03	- 0.1647583 E + 02	0.2073050 E - 03	0.1458667 E + 02
- 0.4060566E - 05	0.1622803 E + 01	- 0.3278255 E - 06	0.1007568 E + 01
- 0.9502401E - 08	0.2729492 E + 00	- 0.8339703 E - 07	- 0.1090820 E + 01

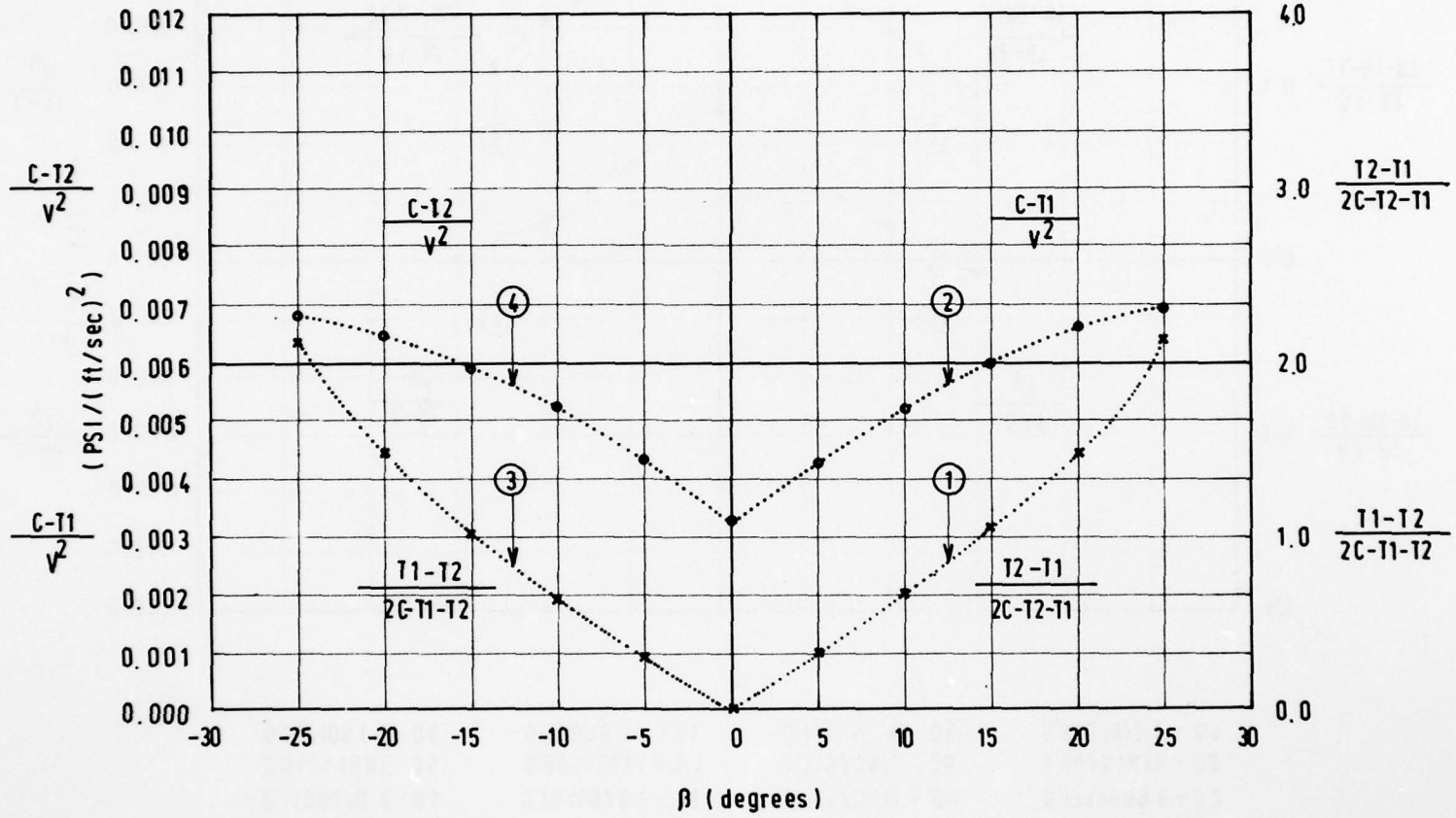


Figure 63 - Post Calibration of Tube 5 in Horizontal-Tangential Plane

AD-A068 486 CHI ASSOCIATES INC ARLINGTON VA F/G 14/2
CALIBRATION OF 5-HOLE AND 13-HOLE PITOT TUBES BEFORE AND AFTER --ETC(U)
DEC 78 R B HURWITZ, M DICK N00600-78-C-0440
UNCLASSIFIED DTNSRDC-SPD-0833-03 NL

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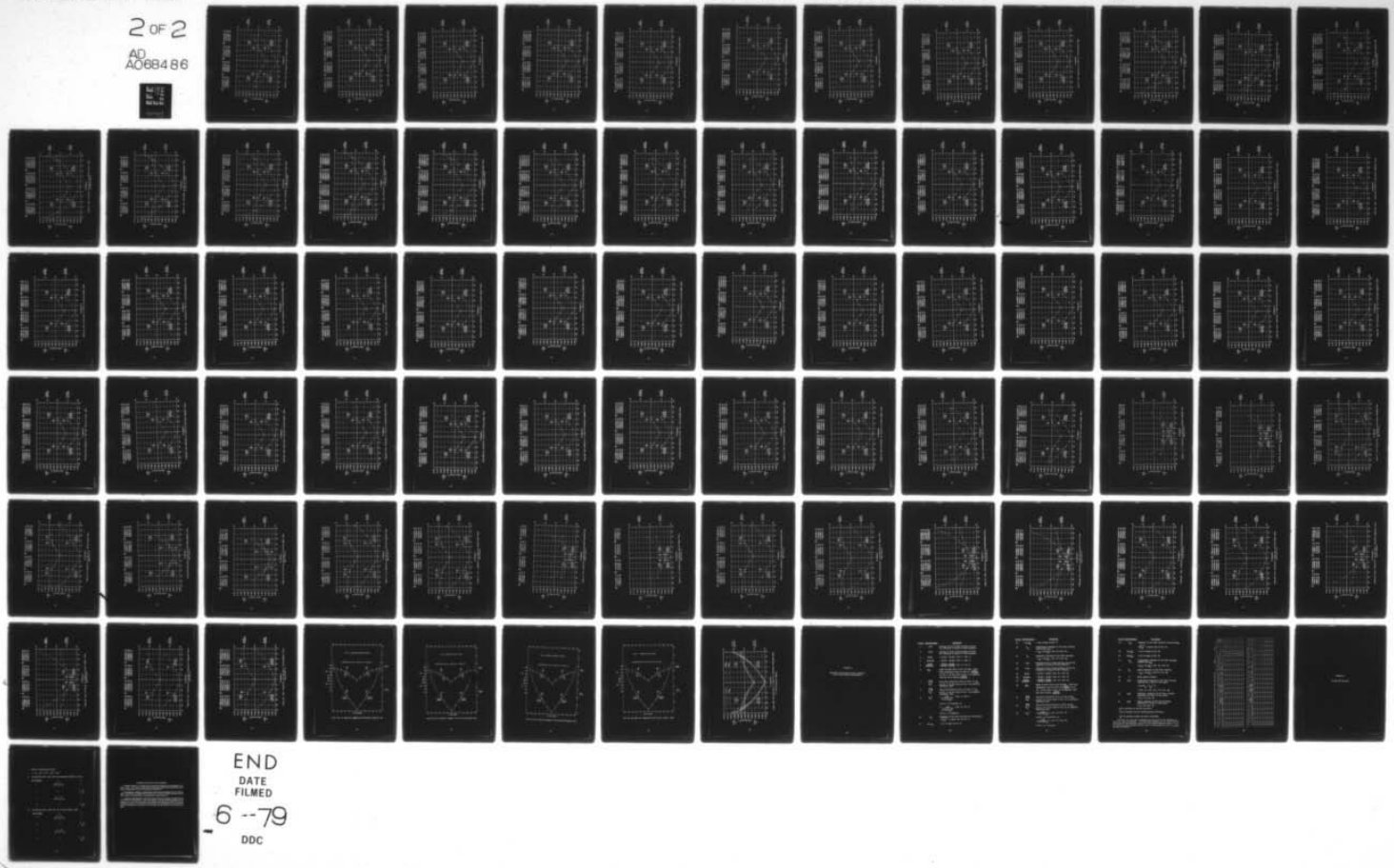

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⑧	⑦	⑥	⑤
0.3321826E-02	0.6010742E+00	0.3341436E-02	-0.4836426E+00
-0.2146326E-03	-0.1984985E+02	0.2366304E-03	0.1537646E+02
-0.3688037E-05	0.5321045E+01	-0.3419816E-05	0.2441406E+00
-0.2475281E-07	-0.8049316E+00	-0.2153683E-08	-0.8144531E+00

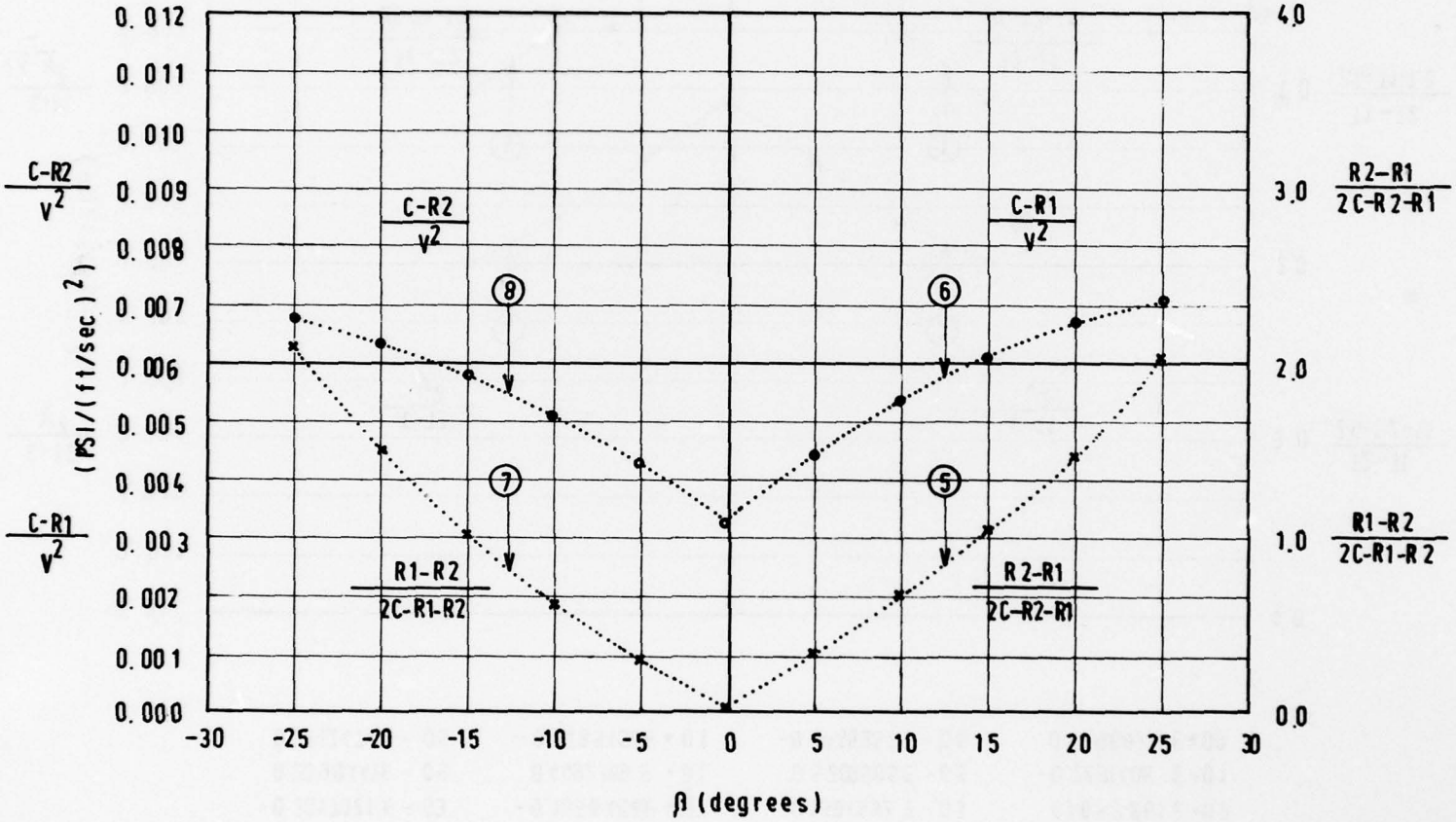


Figure 64 -Post Calibration of Tube 5 in Vertical-Radial Plane

④ 0.3210042E-02	③ 0.3825378E-01	② 0.3210030E-02	① -0.3837585E-01
-0.2017021E-03	-0.1666406E+02	0.1894832E-03	01657861E+02
0.3099442E-05	0.4492188E+01	0.5200505E-05	-0.2691406E+01
0.2712477E-06	-0.2285156E+01	-0.3846362E-06	0.1796875E+00

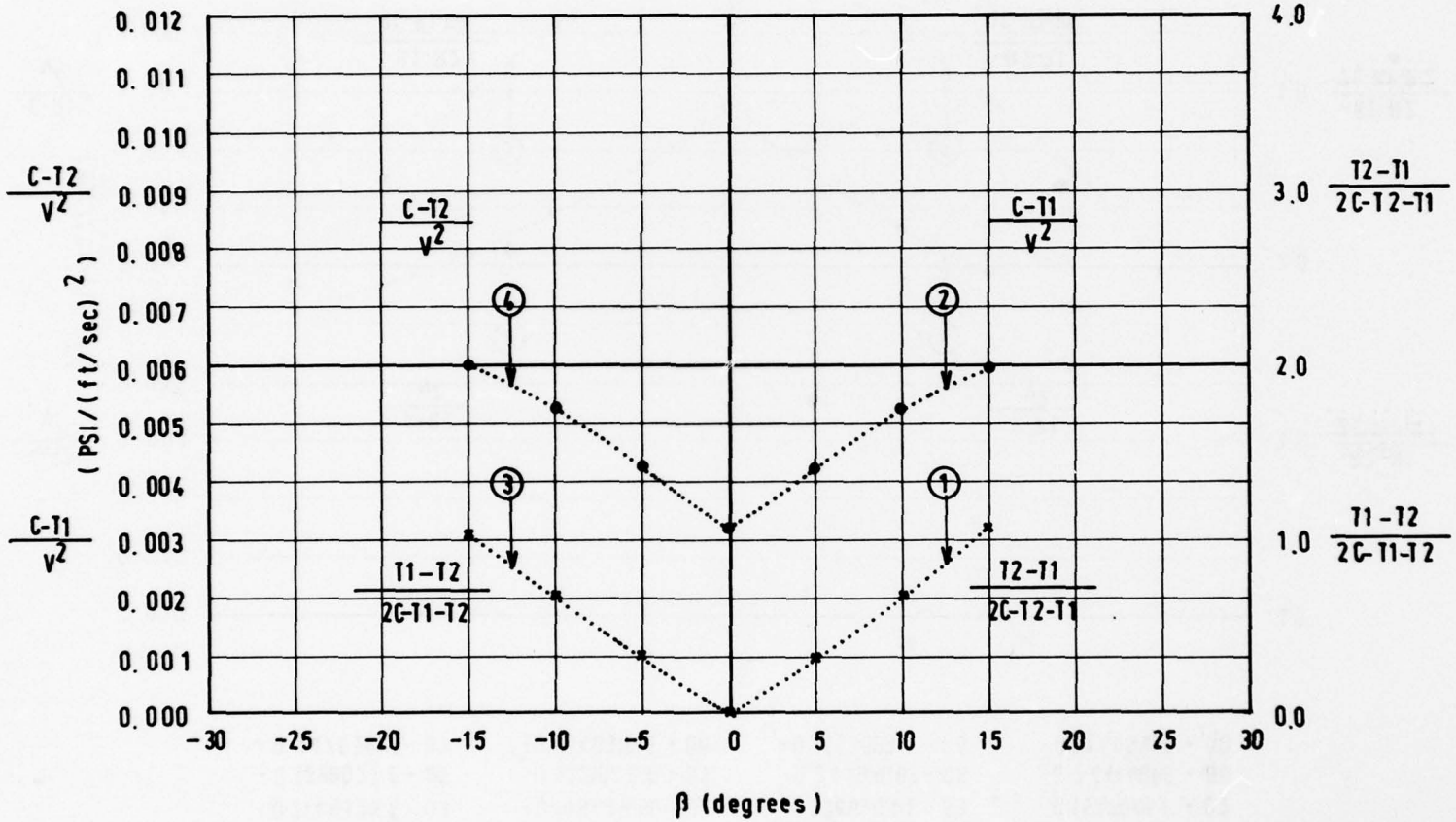


Figure 65 -Post Calibration of Tube 6 in Horizontal-Tangential Plane

⑧ 0.3230013E - 02	⑦ 0.2544708E + 00	⑥ 0.3230035E - 02	⑤ -0.2267914E + 00
-0.2154708E - 03	-0.1730859 E + 02	0.2292395E - 03	0.1537329 E + 02
-0.4813075E - 05	0.4316406 E + 01	-0.2112240E - 05	-0.2656250E + 00
-0.1392327 E - 06	-0.1906250 E + 01	- 0.7264316E - 07	-0.9101563E + 00

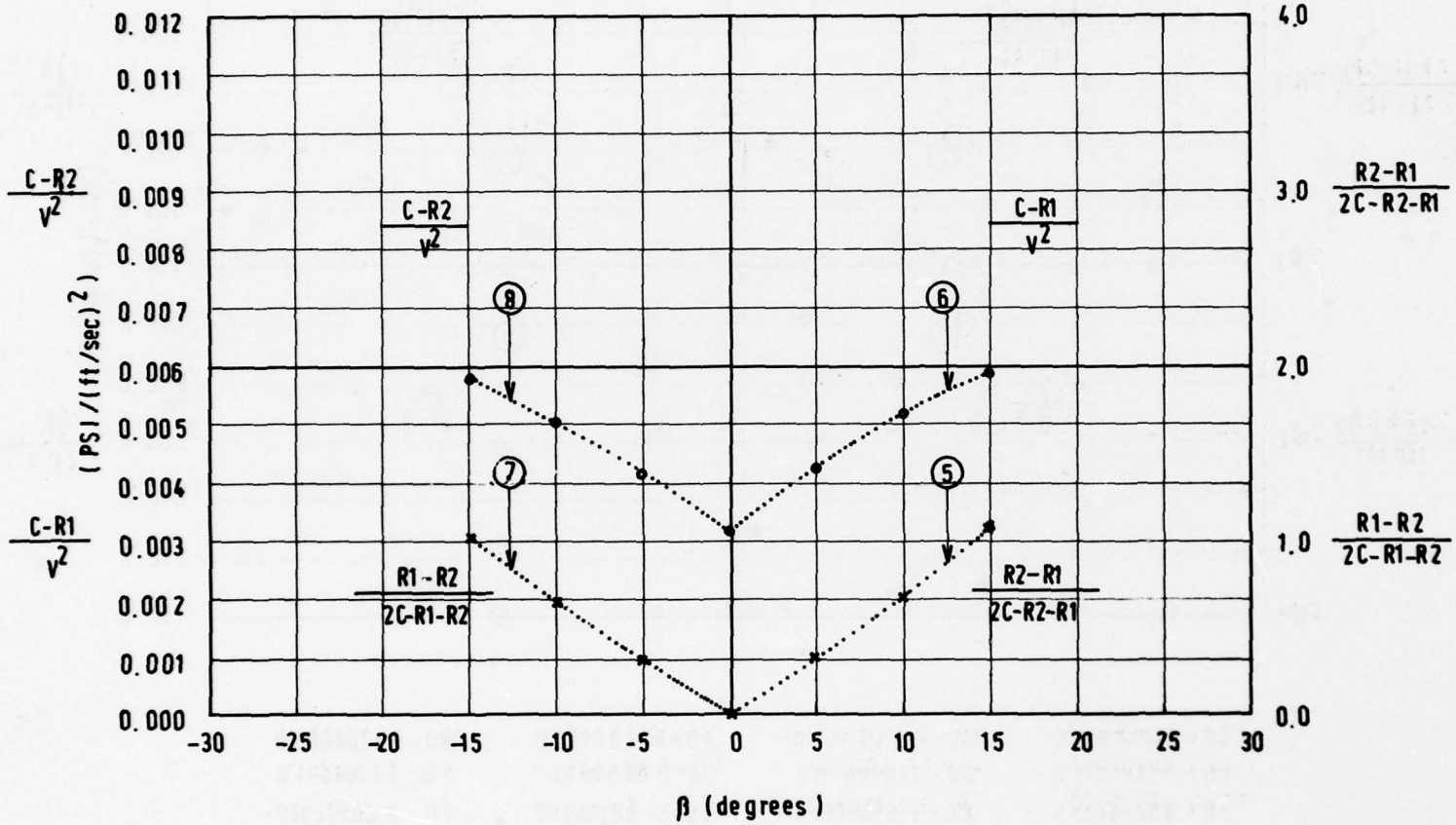


Figure 66 -Post Calibration of Tube 6 in Vertical-Radial Plane

④ 0.3386006 E - 02	③ 0.6542969E - 01	② 0.3386047 E - 02	① -0.7179260E - 01
-0.1675487 E - 03	-0.1548486 E +02	0.1938939 E - 03	0.1703979E + 02
0.1152977 E - 04	-0.2460938 E +00	0.5796552E - 05	-0.4671875 E + 01
0.7092021 E - 06	0.1085938 E +01	-0.4163012 E - 06	0.2062500E + 01

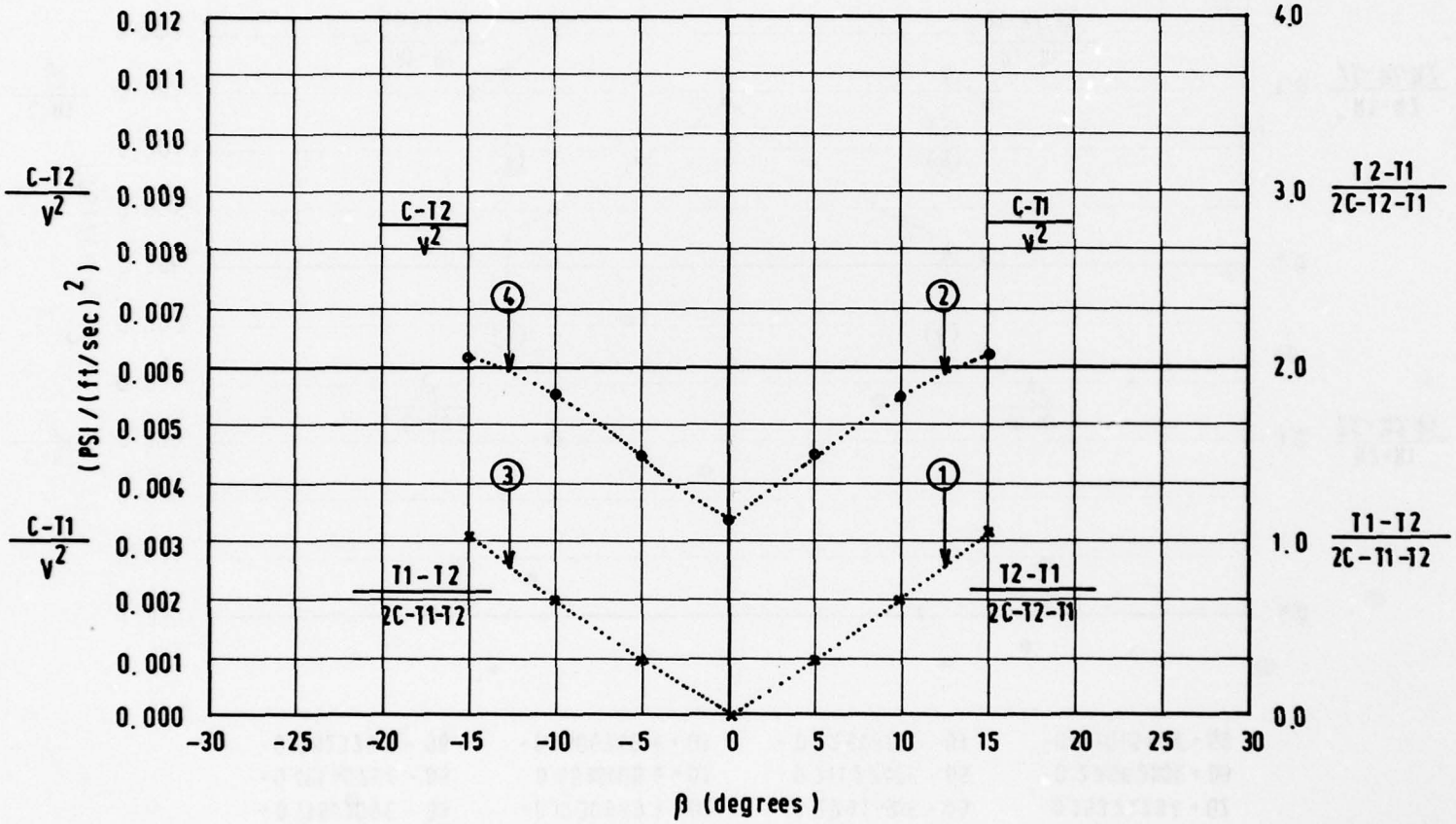


Figure 67 -Post Calibration of Tube 9 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3432006 E-02	0.2711487 E + 00	0.3432024 E-02	-0.2718811 E + 00
-0.1596212 E-03	-0.1540234 E + 02	0.2021194 E-03	0.1548437E + 02
0.9182841 E-05	-0.5269531E + 01	0.1788139 E-05	0.1218750 E + 01
0.5380716 E-06	0.5308594E + 01	-0.2395827E-06	-0.2257813E + 01

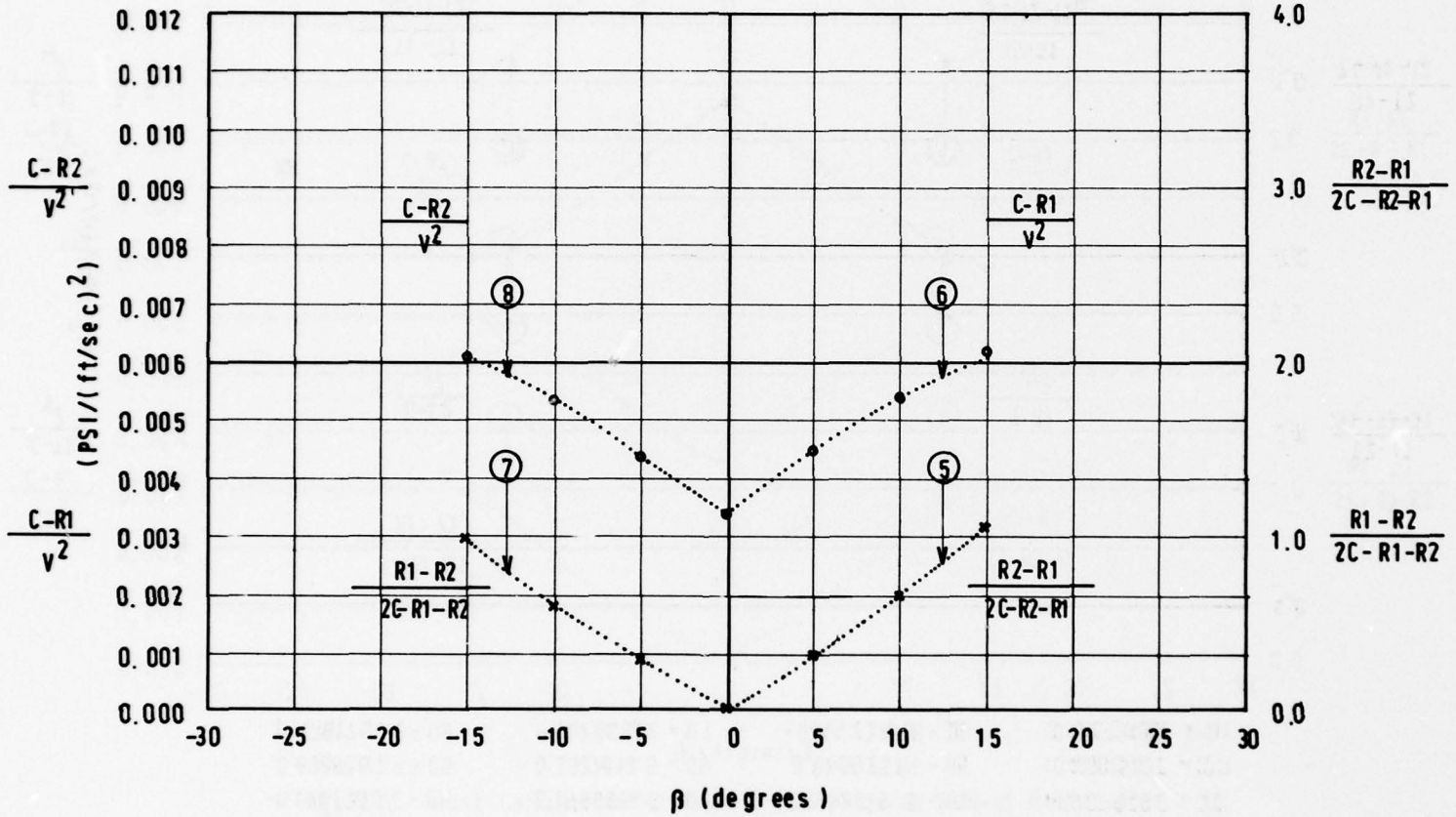


Figure 68 -Post Calibration of Tube 9 in Vertical-Radial Plane

④ 0.3340028 E - 02	③ 0.9747314 E - 01	② 0.3340032E - 02	① -0.1108398E + 00
-0.1747608 E - 03	-0.1556958 E + 02	0.1903176 E - 03	0.1771948 E + 02
0.6888062 E - 05	-0.3632813 E + 00	0.6560236E - 05	-0.6601563E + 01
0.4281756 E - 06	0.1429688E + 01	-0.4423782E - 06	0.3273438E + 01

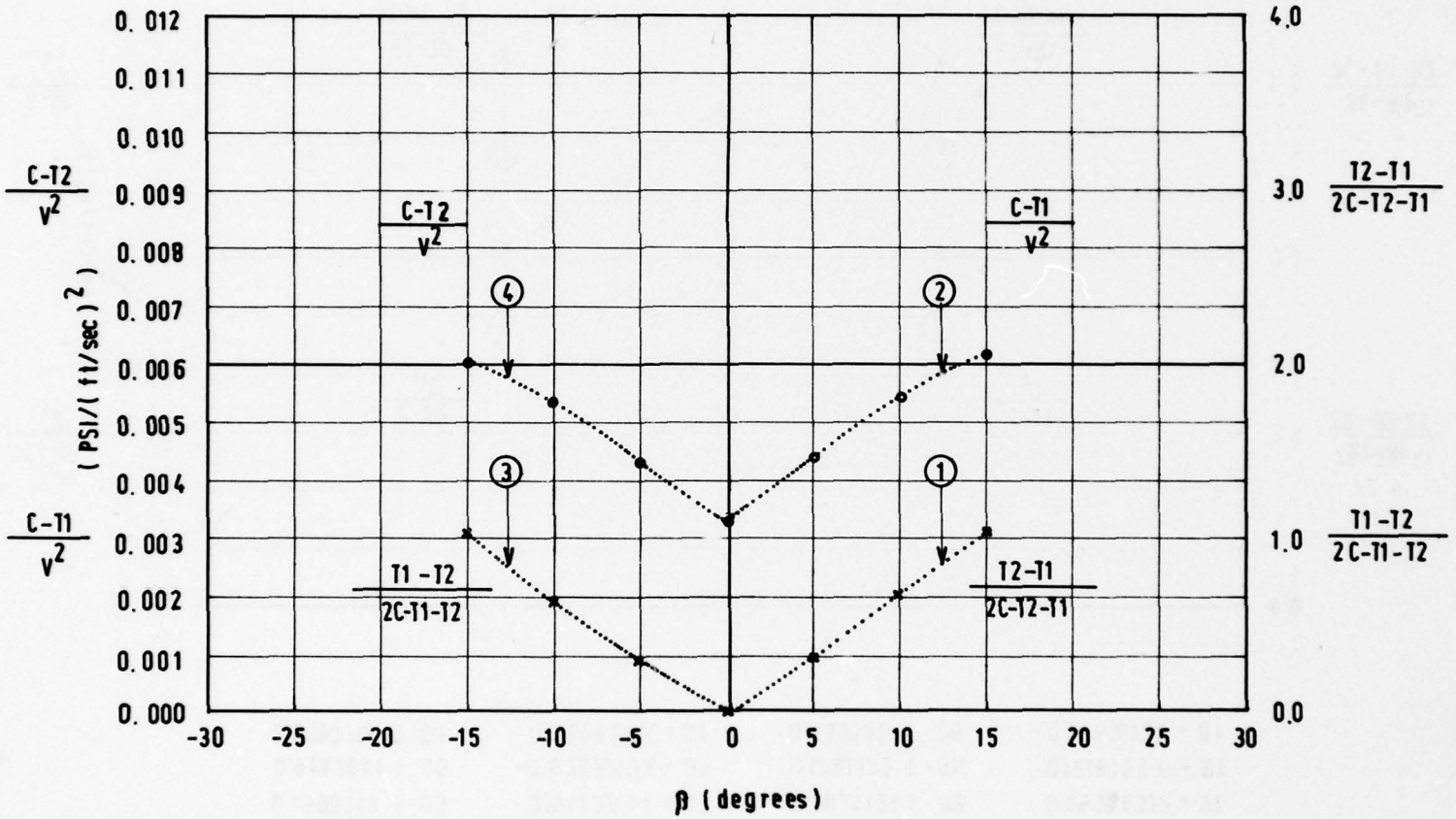


Figure 69 - Post Calibration of Tube 11 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3440030E - 02	0.9091797E + 00	0.3439981E-02	-0.5925293 E +00
-0.1357794E - 03	-0.2495703 E + 02	0.2665520 E - 03	0.1582031 E +02
0.9167939E - 05	0.1732813 E + 02	-0.7025898 E - 05	0.6875000 E +00
0.4444737E - 06	-0.8347656E + 01	0.9196810 E - 07	-0.1933594E + 01

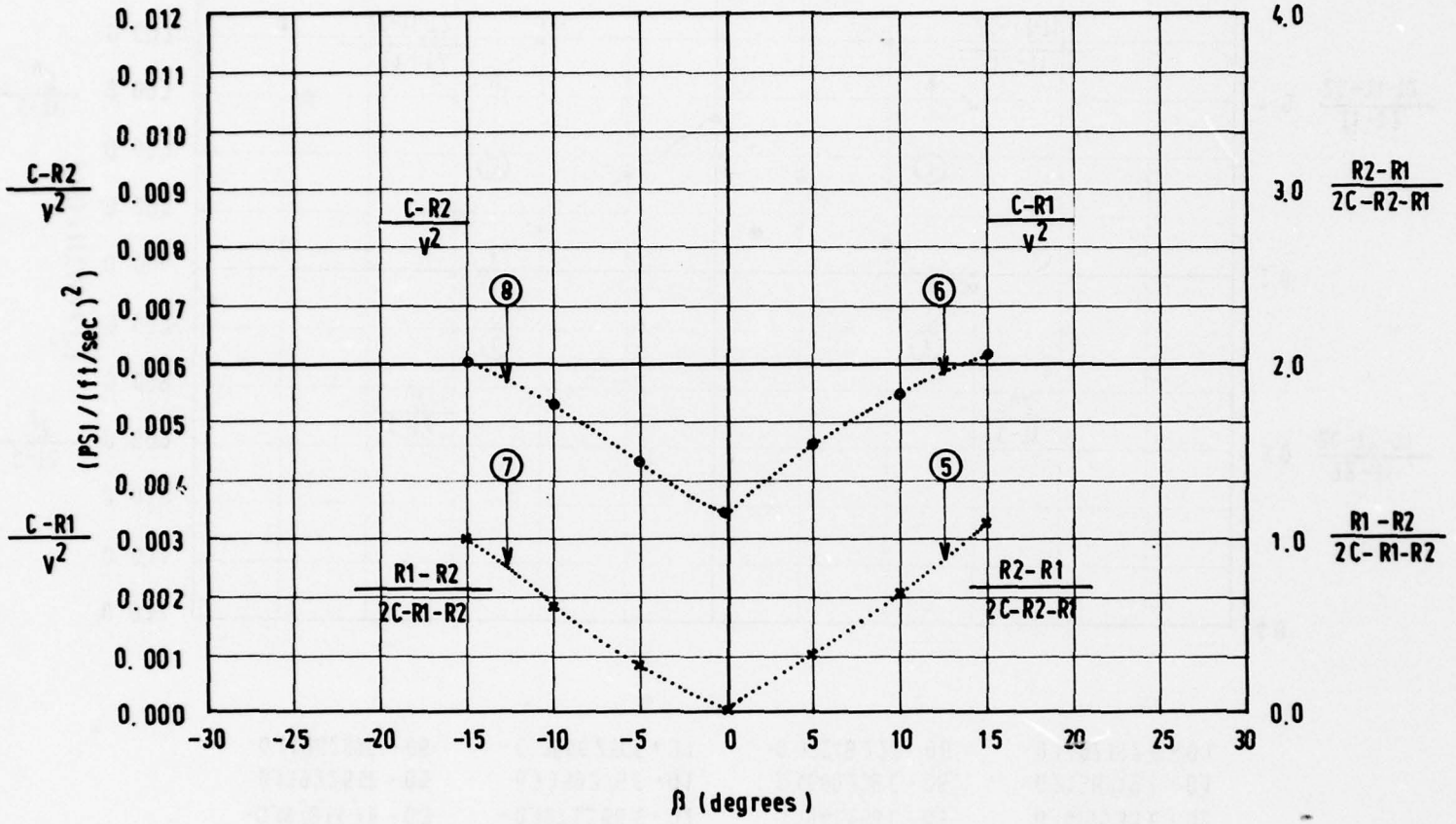


Figure 70 -Post Calibration of Tube 11 in Vertical-Radial Plane

④ 0.3393069 E - 02	③ 0.3496246 E + 00	② 0.3392920 E - 02	① -0.2677612 E + 00
-0.1878142 E - 03	- 0.1872266 E + 02	0.1946688 E - 03	0.1419531 E + 02
0.1393259 E - 05	0.7359375 E + 01	0.4660338 E - 05	0.2136719 E + 01
0.1406297 E - 06	- 0.3656250 E + 01	-0.3324822 E - 06	-0.1492187 E + 01

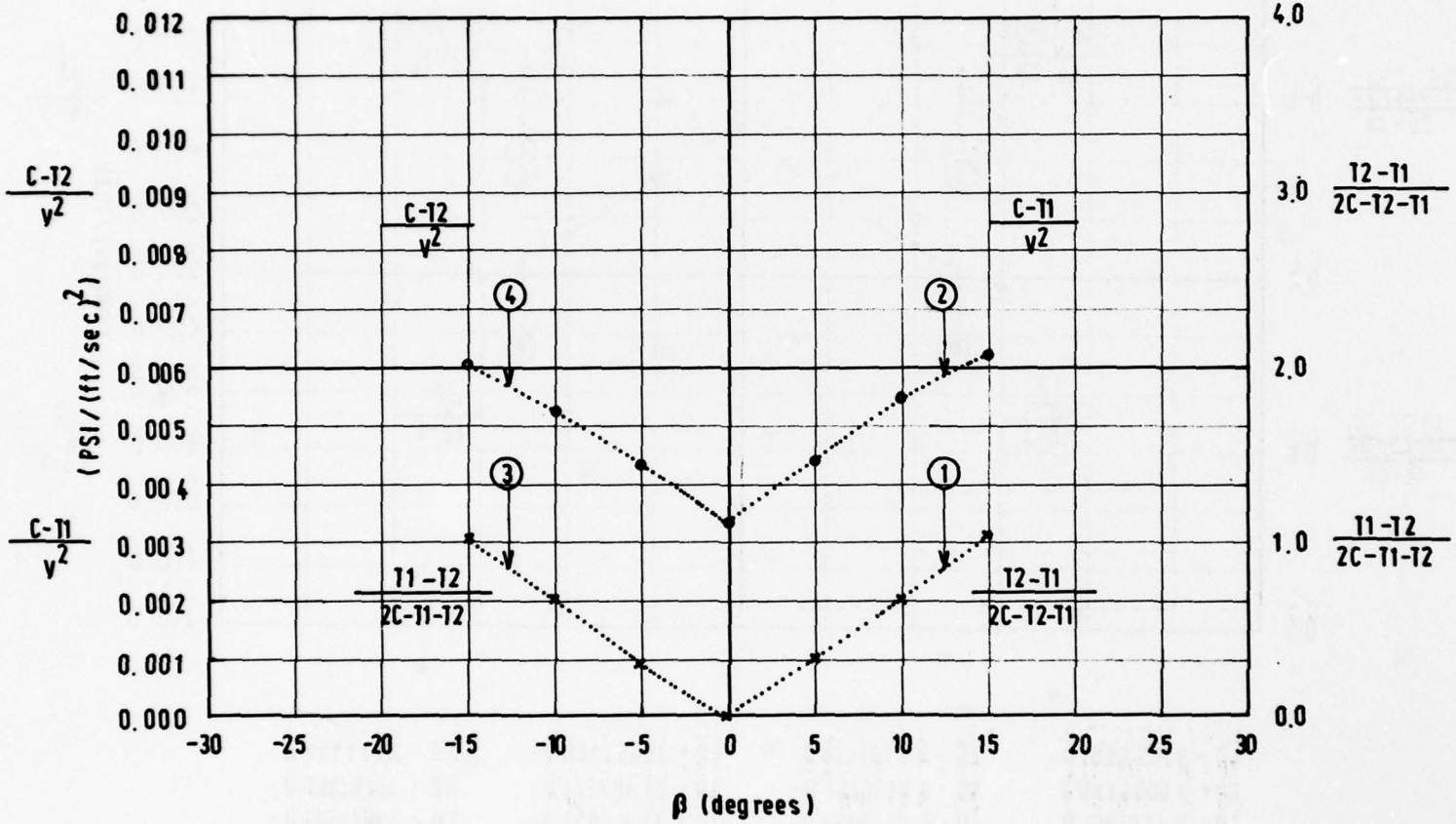


Figure 71 -Post Calibration of Tube 12 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3474955 E-02	0.5268097 E+00	0.3475003 E-02	-0.5061951 E+00
-0.6222725 E-04	-0.1978906 E+02	0.2501011 E-03	0.1919141 E+02
0.2254918 E-04	0.5578125 E+01	-0.1023337 E-04	-0.1148047 E+02
0.1010951 E-05	-0.1316406 E+01	0.3818423 E-06	0.6722656 E+01

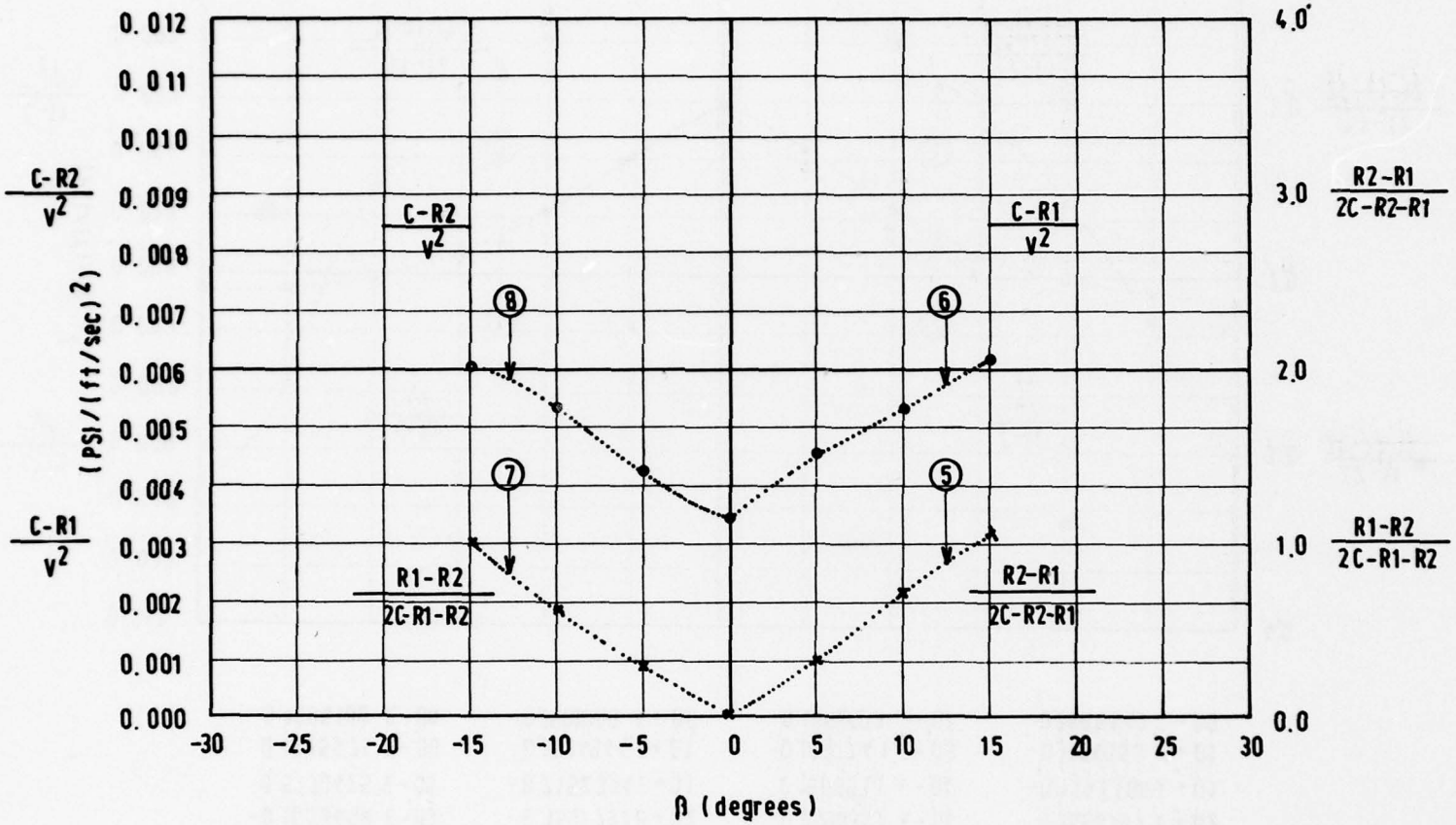


Figure 72 -Post Calibration of Tube 12 in Vertical-Radial Plane

④	③	②	①
0.3065765 E-02	0.6445313 E-01	0.3050864 E-02	-0.2131348 E+00
-0.1673698 E-03	-0.1591797 E+02	0.9590387 E-04	0.1666797 E+02
0.5770475 E-05	-0.2152344 E+01	0.1668930 E-04	-0.1191406 E+01
0.4875474 E-06	0.3714844 E+01	-0.1030741 E-05	-0.1164063 E+01
0.7596100 E-08	-0.7500000 E+00	0.1656008 E-07	0.2685547 E+00

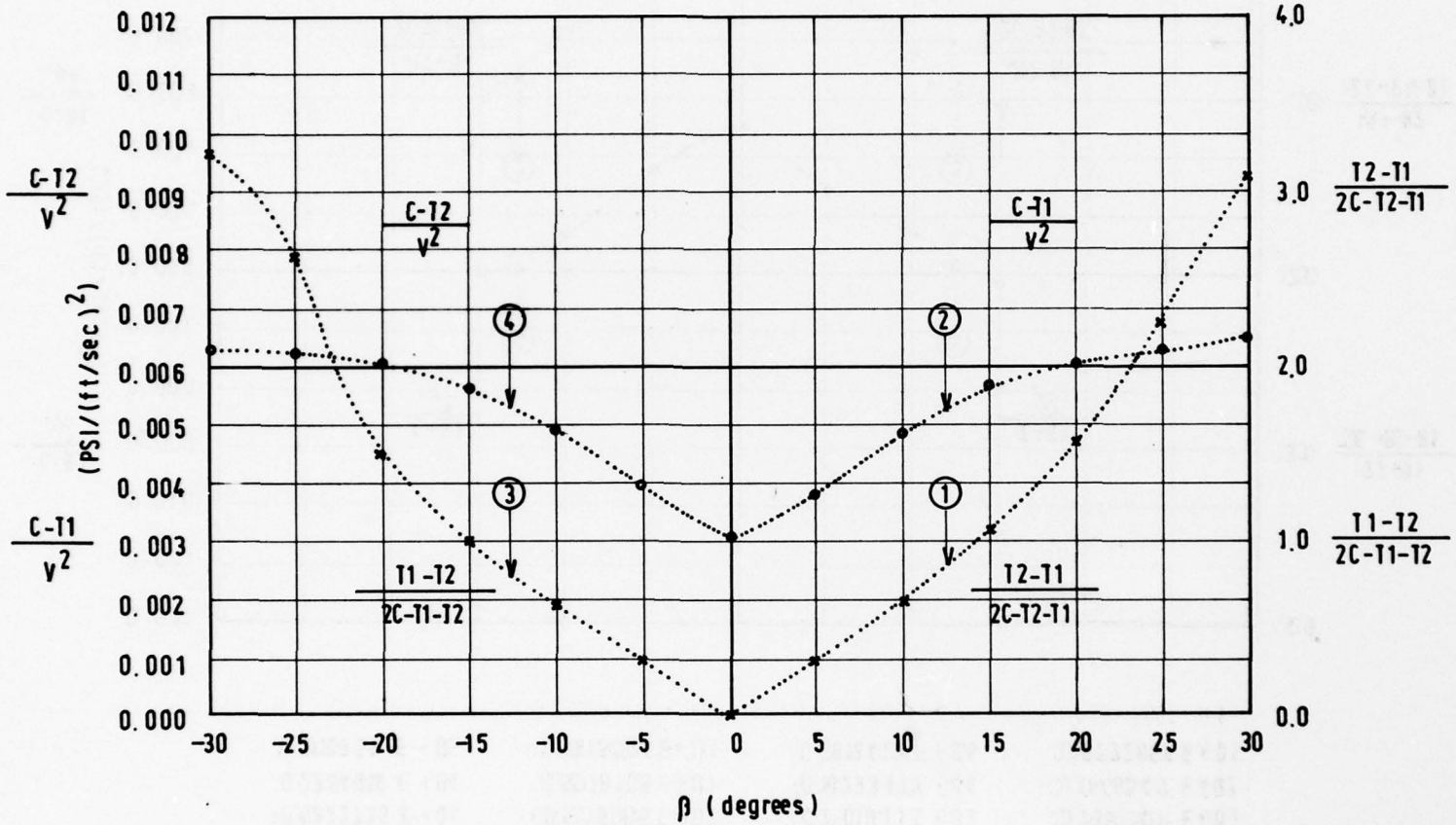


Figure 73 - Post Calibration of Tube 13 in Horizontal-Tangential Plane at 6 feet per second

⑧	⑦	⑥	⑤
0.3075182 E - 02	0.2424316E + 00	0.3092110E-02	0.7568359E-02
-0.3094077 E - 03	-0.1521875E + 02	0.1733303E-03	0.3238281 E + 02
-0.4947186 E - 05	0.3914062E + 01	-0.1907349E-05	-0.3062500E + 02
0.4693866 E - 06	-0.1292969E + 01	0.2384186E-06	0.1937500E + 02
0.1513399 E - 07	0.2460938E + 00	-0.1008448E-07	-0.4562500E + 01

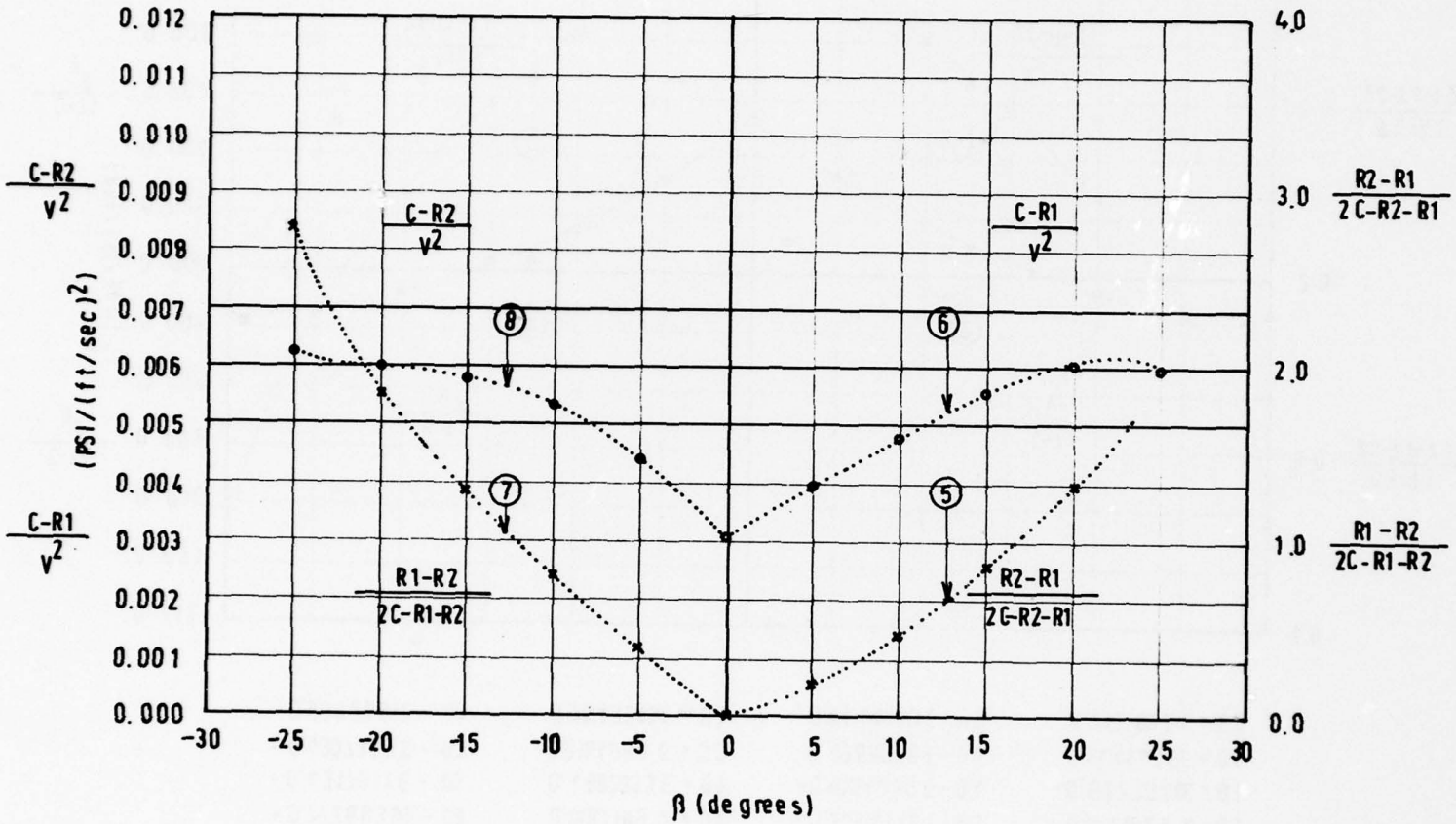


Figure 74 -Post Calibration of Tube 13 in Vertical - Radial Plane at 6 feet per second

④ 0.3364563 E - 02	③ 0.5932617 E - 01	② 0.3358006 E - 02	① -0.9375000 E - 01
-0.2226830E - 03	0.1887109 E + 02	0.2334118 E - 03	0.1844922 E + 02
-0.4317611 E - 05	0.4882813 E + 01	-0.1054257 E - 04	-0.5277344E + 01
-0.4307367 E - 07	-0.8164063 E + 00	0.4966278 E - 06	0.1441406E + 01
-0.6693881E - 09	0.7543945E - 01	-0.9444193E - 08	-0.2121582 E + 00

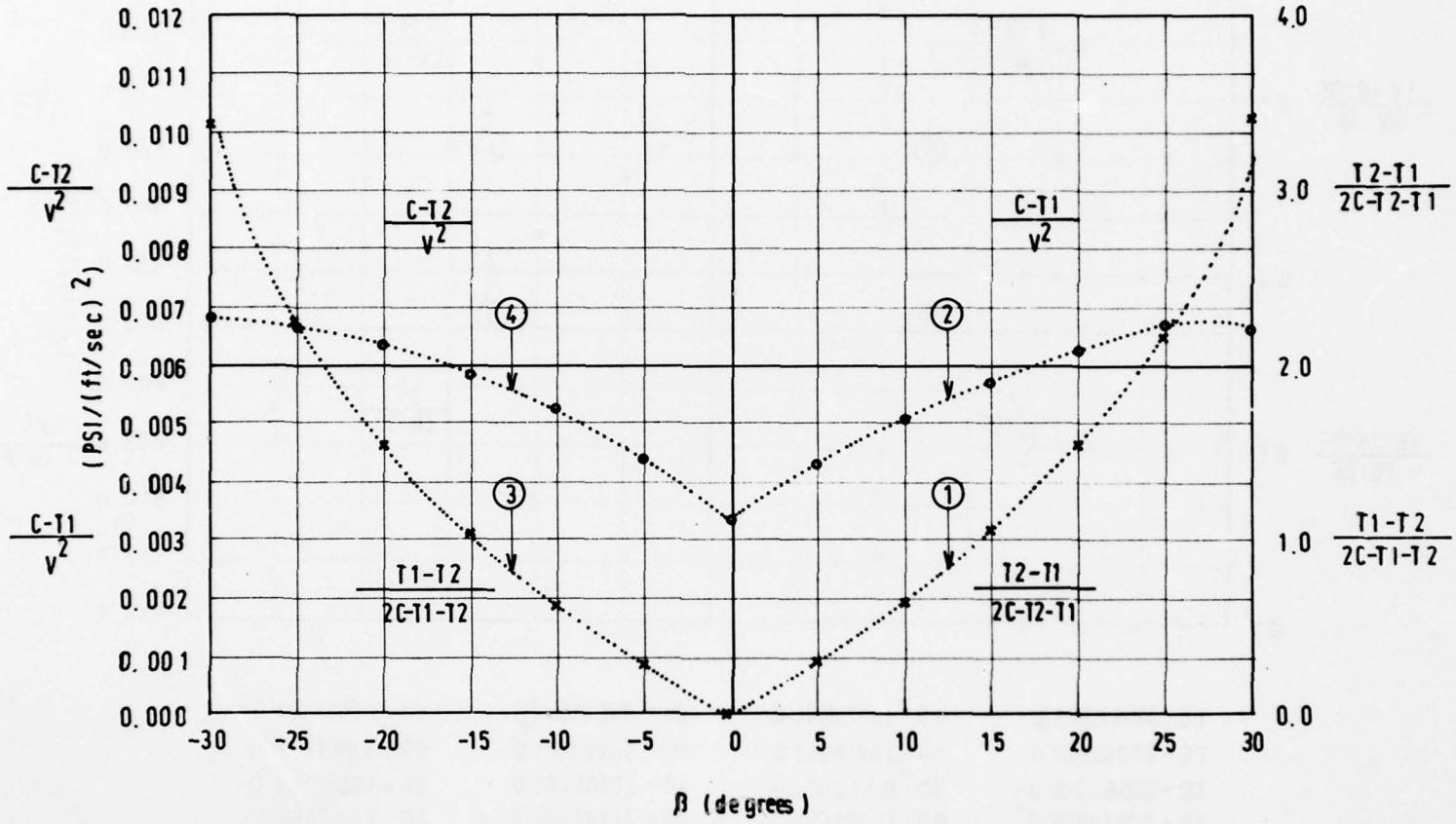


Figure 75 -Post Calibration of Tube 13 in Horizontal-Tangential Plane at 11feet per second

⑧ 0.3372848E-02	⑦ 0.4272461E-01	⑥ 0.3353894E-02	⑤ -0.6591797E-02
-0.1168847E-03	-0.1608984 E+02	0.1702905 E-03	0.1558984 E+02
0.9097159 E-05	-0.4062500 E+00	0.3971159E-05	-0.4414063E+00
0.5650800 E-06	0.2078125 E+01	-0.3527384E-06	-0.9687500 E+00
0.8440111E-08	-0.4023438 E+00	0.5704351E-08	0.1528320 E+00

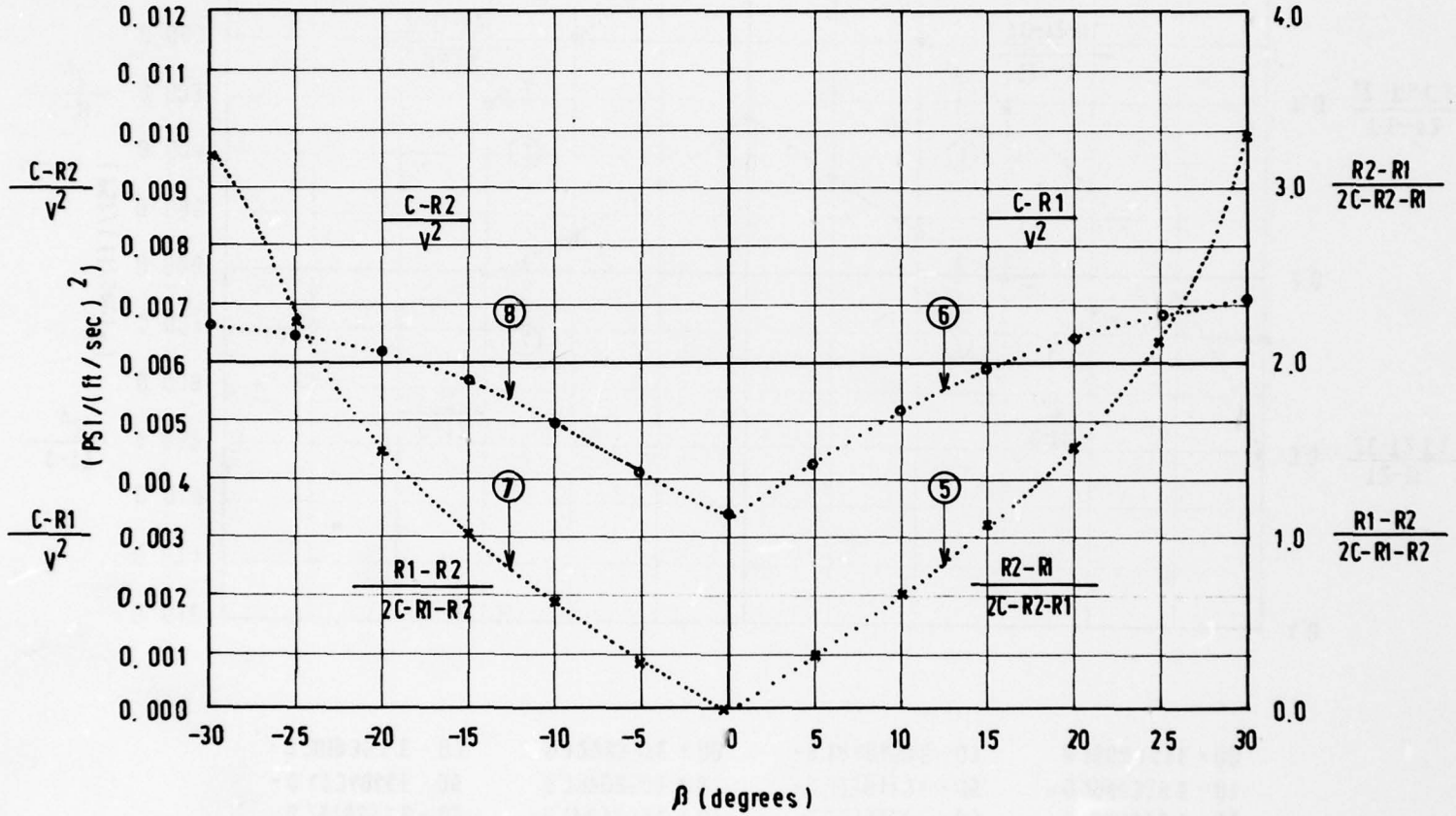


Figure 76 -Post Calibration of Tube 13 in Vertical-Radial Plane at 11 feet per second

④ 0.3311753 E - 02	③ 0.3154297 E + 00	② 0.3291488 E - 02	① - 0.2514648 E + 00
- 0.2515353 E - 03	- 0.1743359 E + 02	0.2313927 E - 03	0.1758423 E + 02
- 0.4734844 E - 05	0.2870850 E + 01	- 0.3036112 E - 05	- 0.2986328 E + 01
- 0.2018351 E - 07	- 0.1228027 E + 00	- 0.1446460 E - 07	0.1564941 E + 00

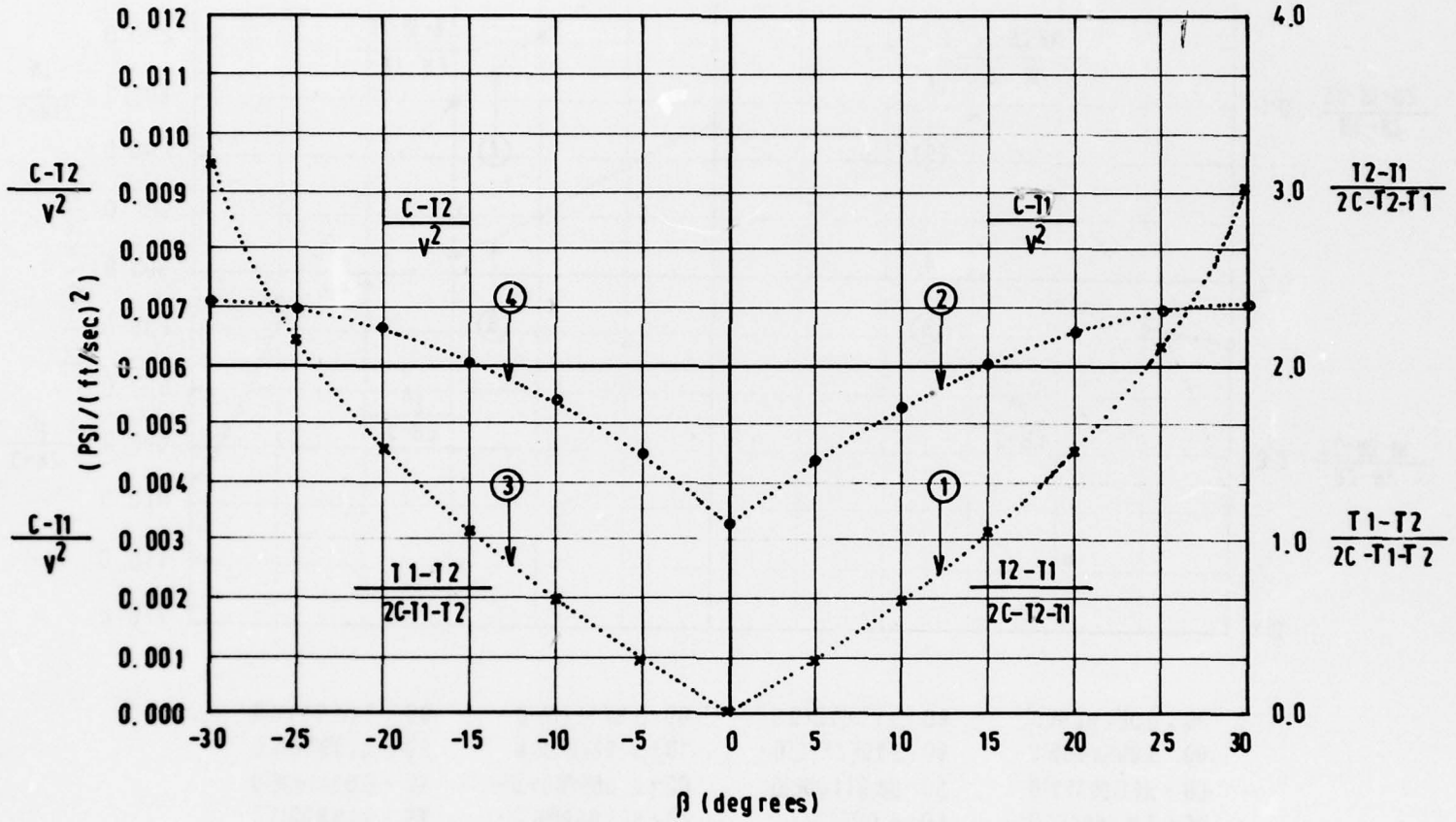


Figure 77 - Post Calibration of Tube 13 in Horizontal-Tangential Plane at 20 feet per second

⑧ 0.3377259E-02	⑦ 0.4455566E+00	⑥ 0.3392637E-02	⑤ -0.5705566E+00
-0.1965128E-03	-0.1854077E+02	0.2215933E-03	0.1765991E+02
-0.1177192E-05	0.3607666E+01	-0.2261251E-05	-0.3016846E+01
0.4444155E-07	-0.2480469E+00	-0.2444722E-07	0.1591797E+00

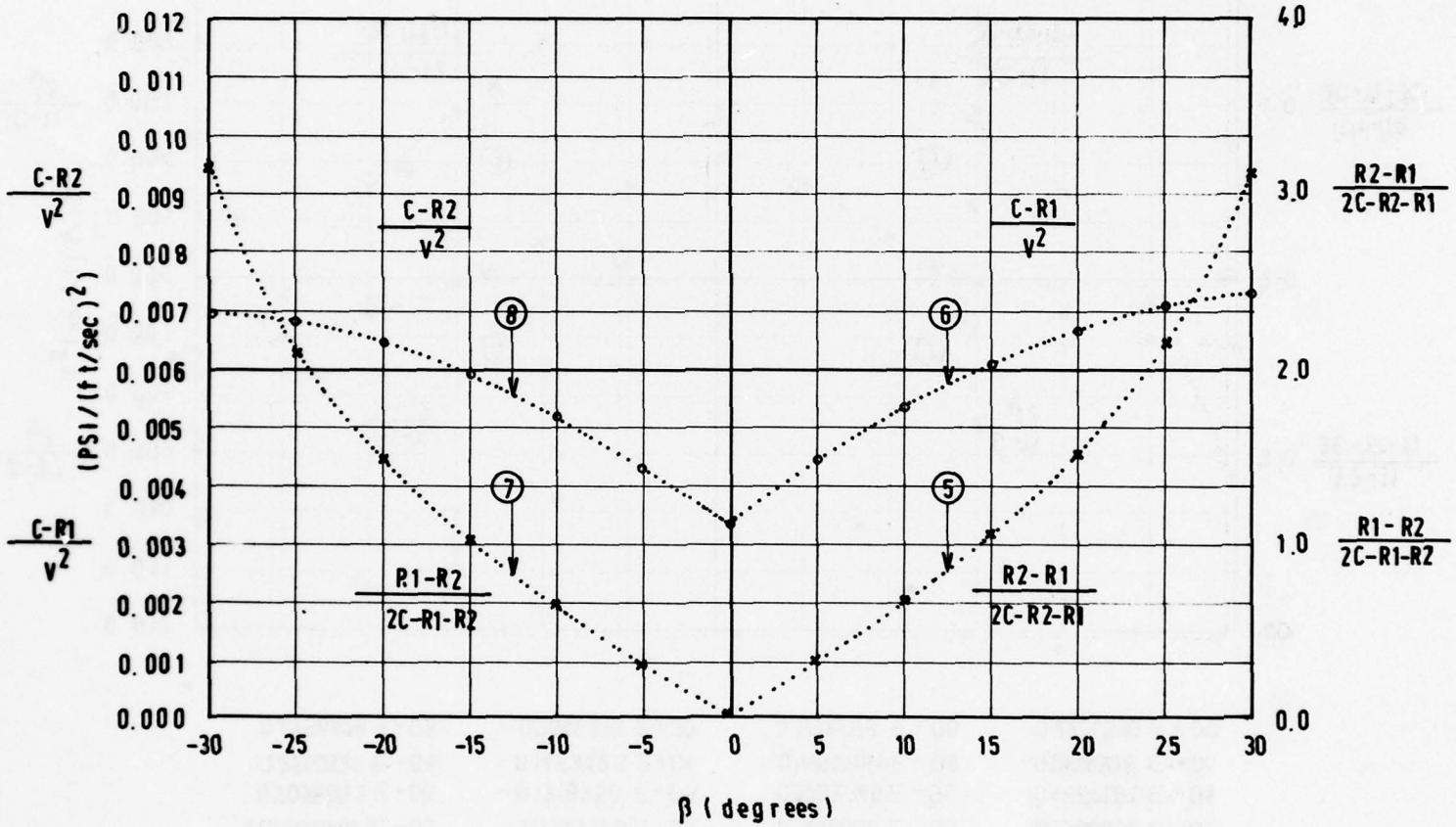


Figure 78 -Post Calibration of Tube 13 in Vertical-Radial Plane at 20 feet per second

④	③	②	①
0.3291309 E-02	0.6201172 E-01	0.3284276E-02	-0.4418945 E-01
-0.2176166 E-03	-0.1559375 E+02	0.1690063 E-03	0.1560938 E+02
0.7078052 E-06	-0.1718750 E+00	0.3792346 E-05	0.1562500 E-01
0.2568122 E-06	0.1453125 E+01	-0.3697351 E-06	-0.1308594 E+01
0.4758476 E-08	-0.2595215 E+00	0.5908078 E-08	0.2204590 E+00

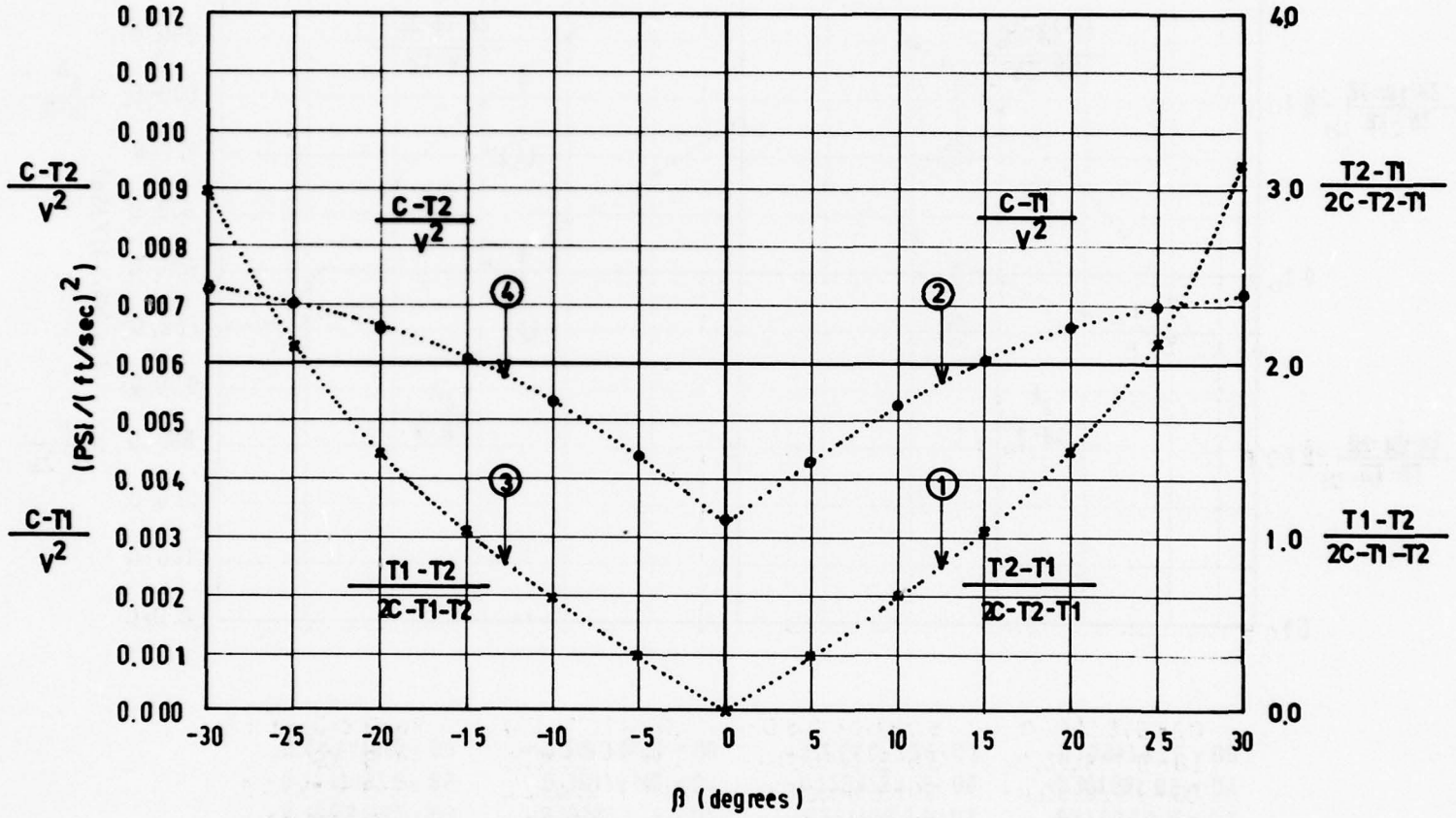


Figure 79 -Post Calibration of Tube 13 in Horizontal-Tangential Plane at 25 feet per second

⑧	⑦	⑥	⑤
0.3417075 E-02	0.6669922 E+00	0.3428340 E-02	-0.4990234 E+00
-0.1548529 E-03	-0.2131641 E+02	0.2208352 E-03	0.1591406 E+02
0.4604459 E-05	0.7378906 E+01	-0.2678484 E-05	-0.1796875 E+00
0.3010500 E-06	-0.1902344 E+01	0.1513399 E-07	-0.1257812 E+01
0.3507012 E-08	0.2434082 E+00	-0.9604264 E-09	0.2177734 E+00

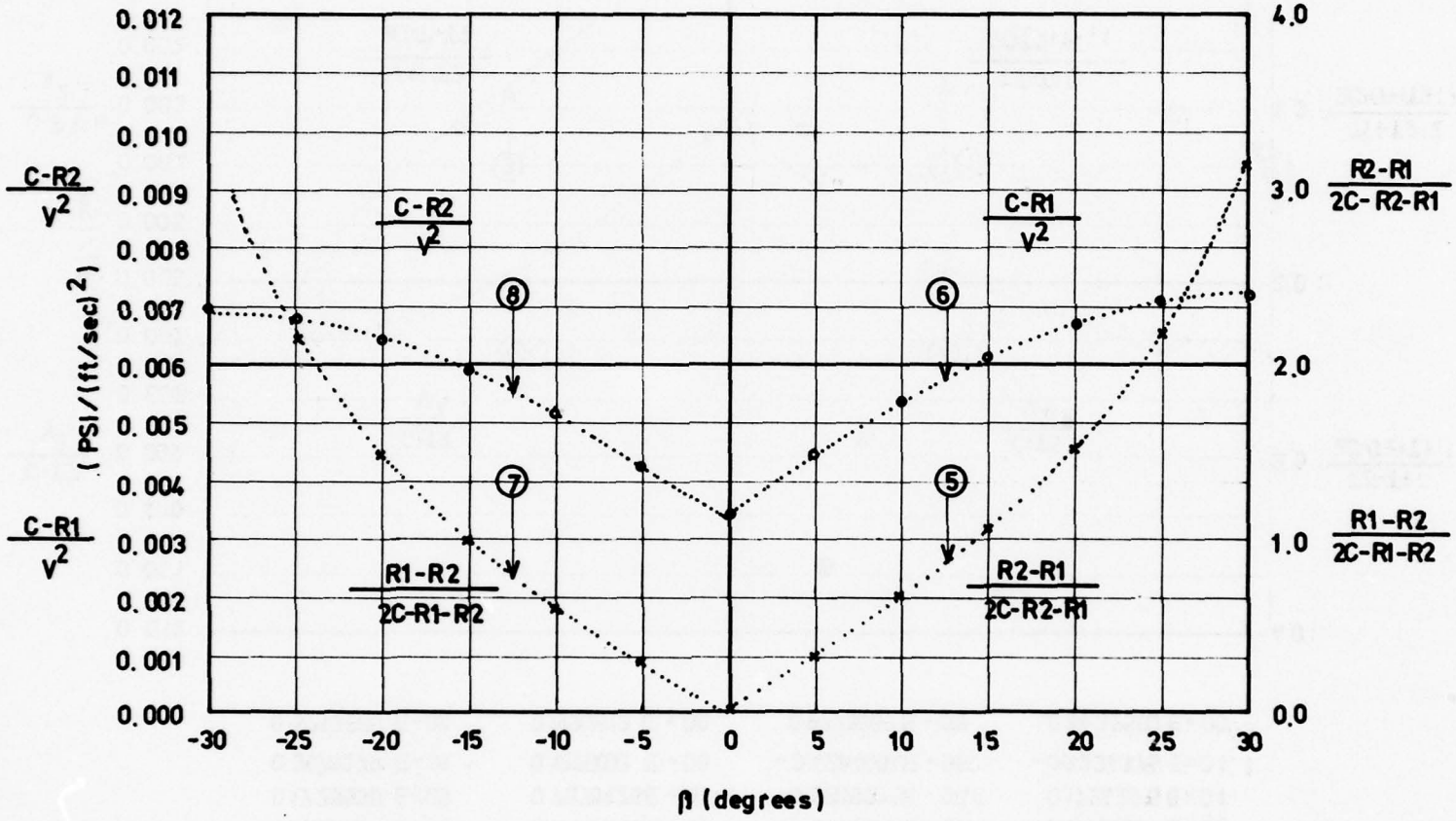


Figure 80 - Post Calibration of Tube 13 in Vertical-Radial Plane at 25 feet per second

④ 0.3239453E-02	③ 0.8032227E-01	② 0.3241539E-02	①-0.5615234E-01
-0.2318621 E-03	-0.1558203E+02	0.2188087E-03	0.1542188 E+02
0.1728535 E-05	0.7578125E+00	0.2205372E-05	0.1734375 E+01
0.3576279 E-06	0.1875000 E+00	-0.4284084E-06	-0.3234375 E+01
0.6213668 E-08	0.1132813 E+00	0.9778887E-08	0.8437500 E+00

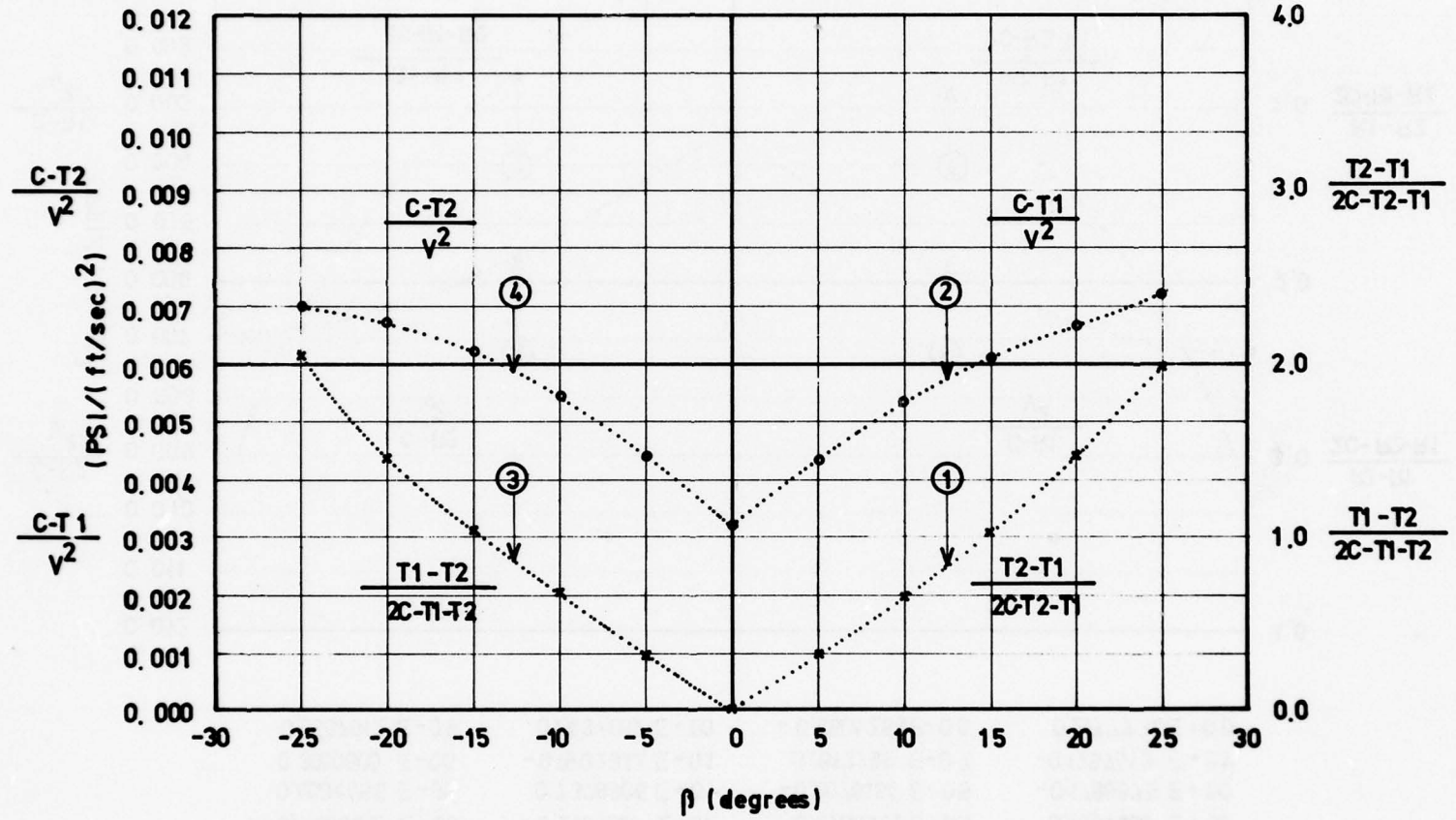


Figure 81 -Post Calibration of Tube 15 in Horizontal-Tangential Plane

⑧ 0.3551066 E-02	⑦ 0.1074463 E+01	⑥ 0.3558815 E-02	⑤ -0.9475098 E+00
-0.1345277 E-03	-0.2233252E+02	0.2334118 E-03	0.1592236 E+02
0.3520399 E-05	0.7078125 E+01	-0.3404915 E-05	-0.9978027 E+00
0.1407461 E-06	-0.1211670 E+01	-0.6679329E-08	-0.4084473 E+00

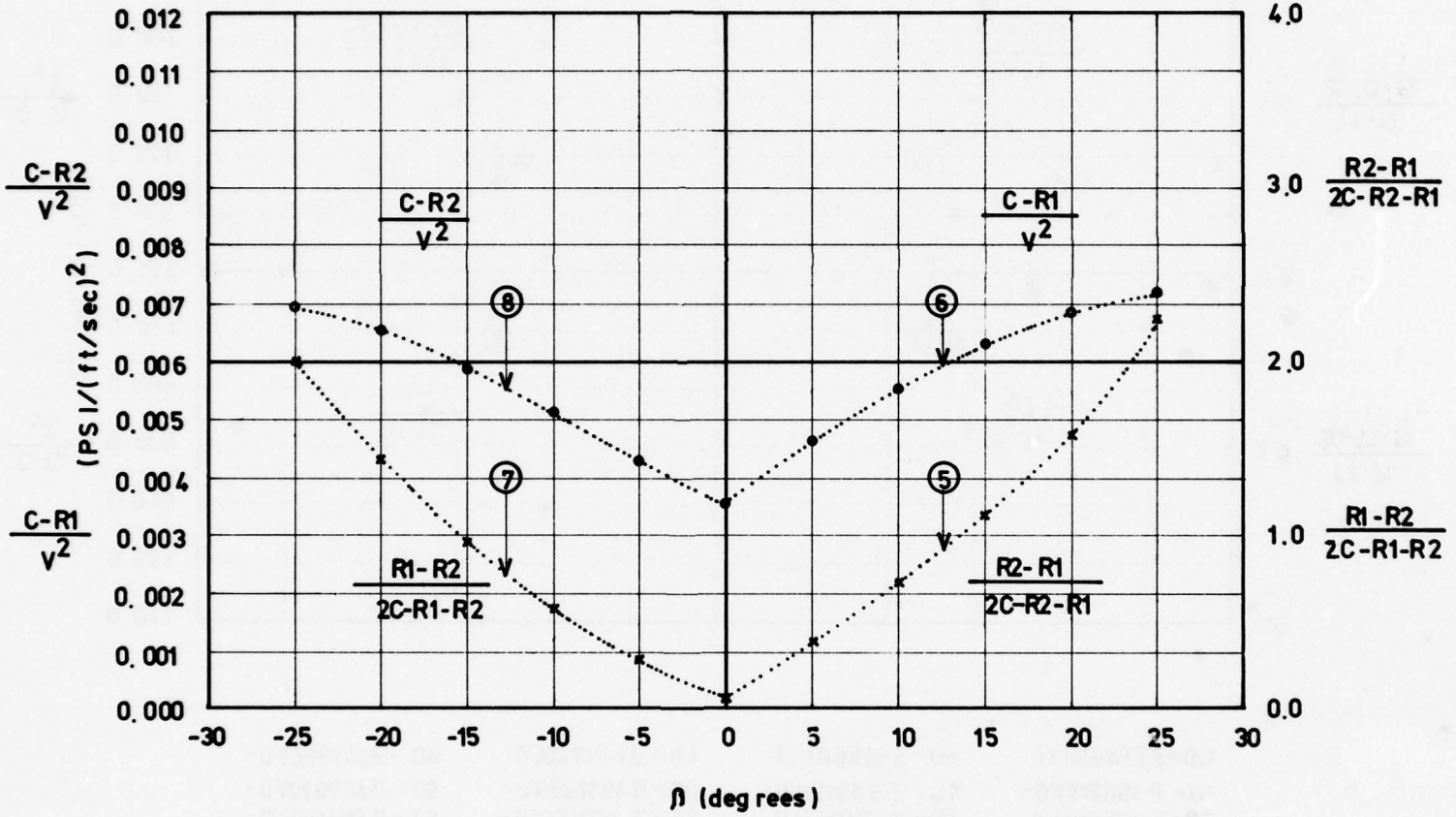


Figure 82 -Post Calibration of Tube 15 in Vertical-Radial Plane

④ 0.3479183 E - 02	③ 0.6494141 E + 00	② 0.3485978 E - 02	① -0.6127930 E+00
-0.2688766 E - 03	-0.1557886 E + 02	0.1747608 E - 03	0.1963135 E+02
-0.4645437 E - 05	-0.6772461 E + 00	0.1251698 E - 05	-0.4449951 E+01
-0.6286427E - 08	0.1024658 E + 01	-0.1109875 E - 06	0.4465332 E+00

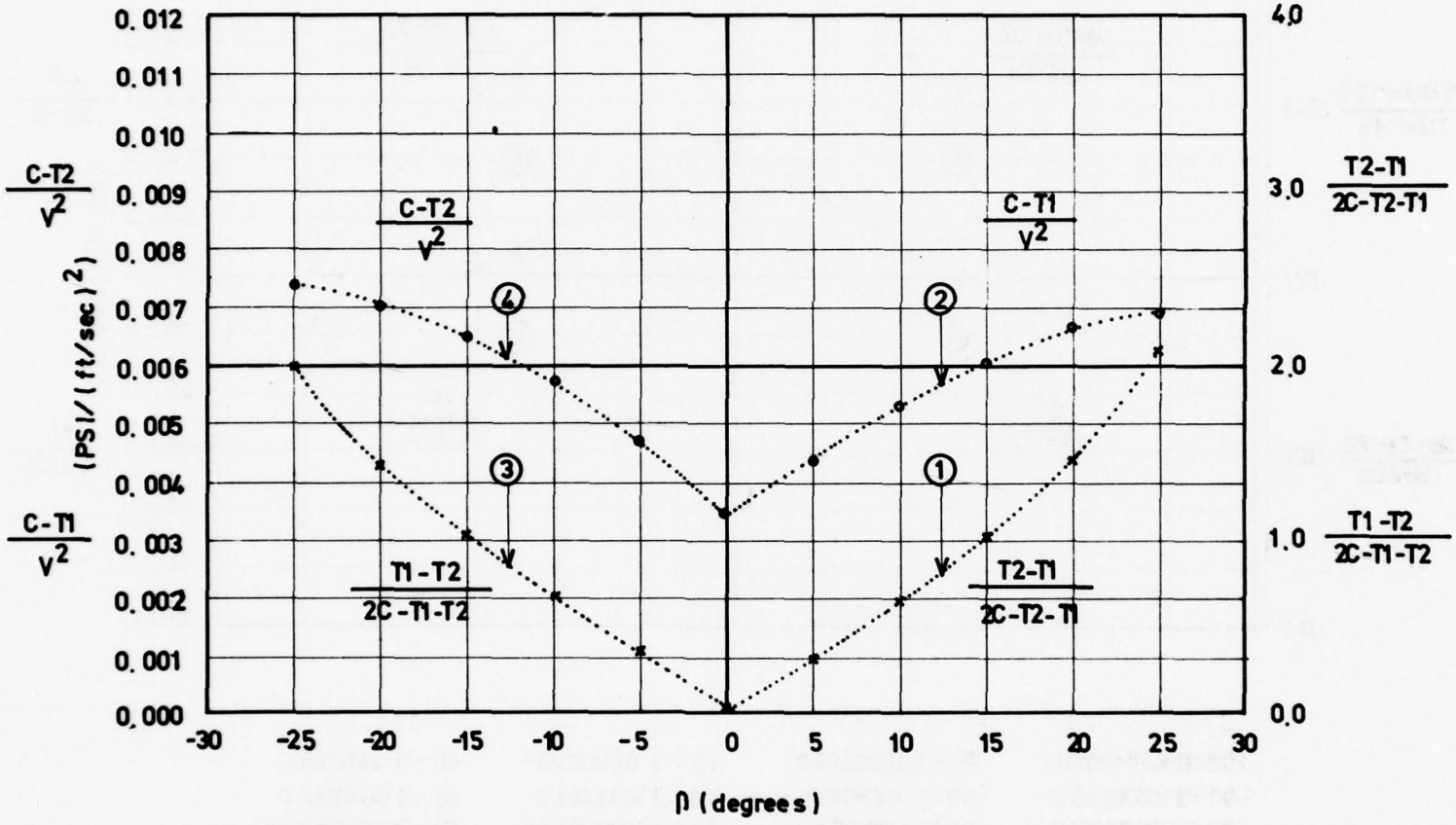


Figure 83 -Post Calibration of Tube 16 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3506243 E-02	0.9416504 E+00	0.3498912 E-02	-0.7287598E+00
-0.1227260 E-03	-0.2258984 E+02	0.1988411 E-03	0.1548437E+02
0.7092953 E-05	0.9687500 E+01	0.1490116 E-05	0.2343750 E+00
0.3501773 E-06	-0.3718750E+01	-0.2570450 E-06	-0.2078125 E+01
0.3186869 E-08	0.6796875E+00	0.4496542 E-08	0.5078125 E+00

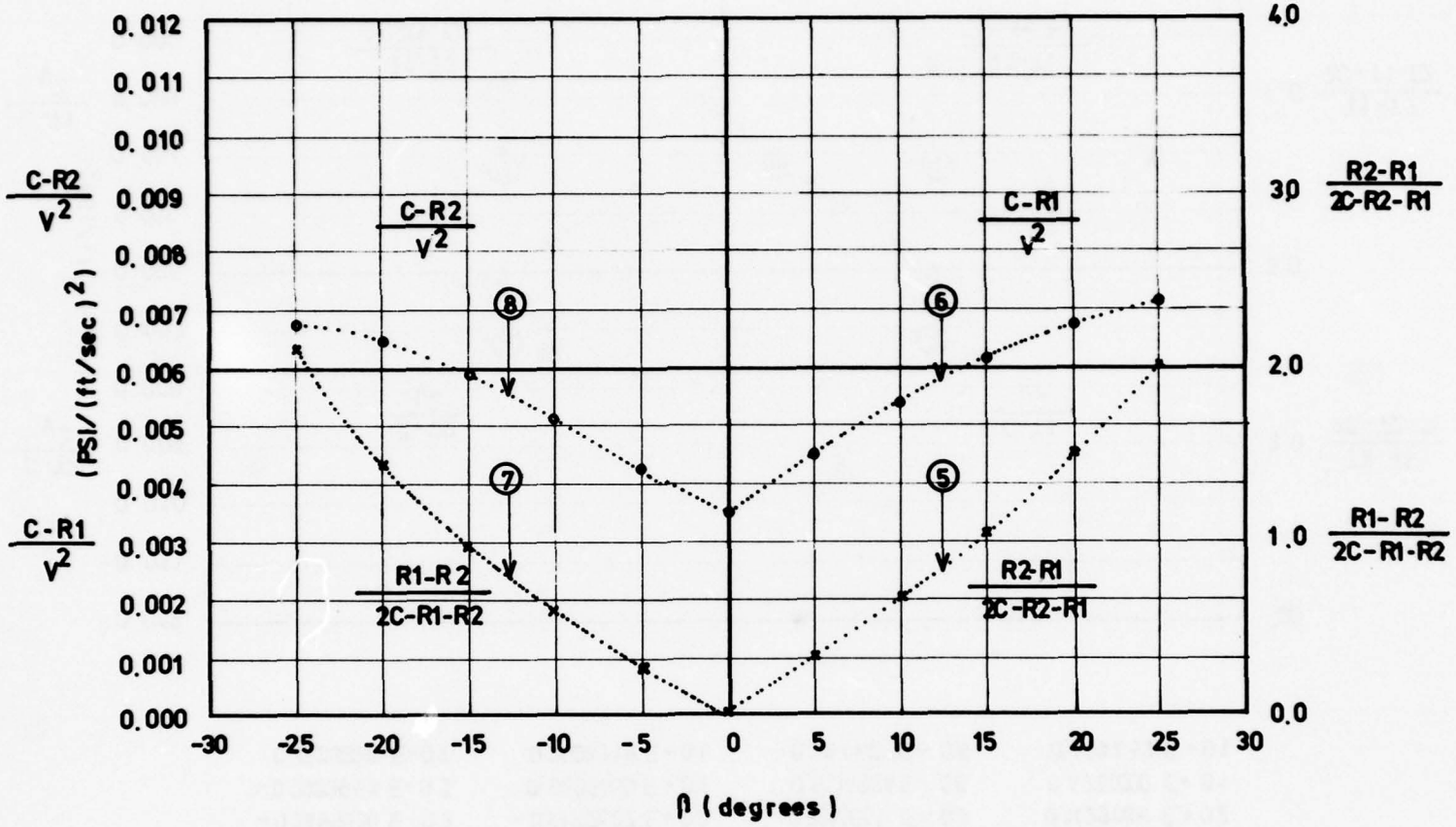


Figure 84 - Post Calibration of Tube 16 in Vertical-Radial Plane

④ 0.3362034 E-02	③ 0.6489563 E-01	② 0.3361948 E-02	① -0.5229187 E-01
-0.2495050 E-03	-0.1772607 E+02	0.2014041 E-03	0.1429688 E+02
-0.2983958 E-05	0.5605469 E+01	0.5114824 E-05	0.4750000 E+01
0.4633330 E-07	0.2636719 E+01	-0.3641471 E-06	-0.4394531 E+01

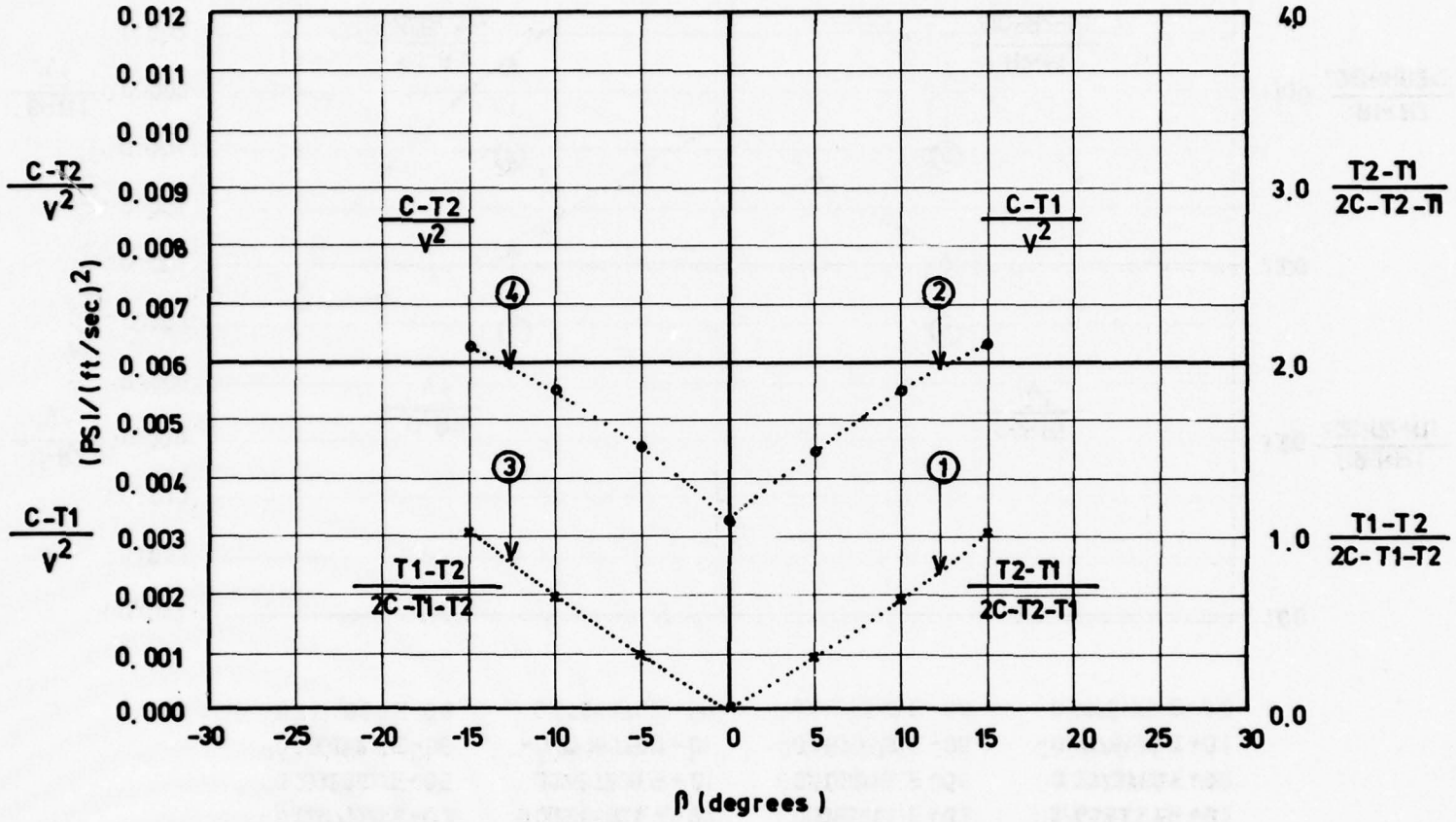


Figure 85 - Post Calibration of Tube 17 in Horizontal - Tangential Plane

⑧	⑦	⑥	⑤
0.3503993 E-02	0.5004272 E+00	0.3503986 E-02	-0.4196625 E+00
-0.1362562 E-03	-0.2089453 E+02	0.2005696 E-03	0.1745703 E+02
0.9741634 E-05	0.1078125 E+02	0.1370907 E-05	-0.6367188 E+01
0.4738104 E-06	-0.5082031 E+01	-0.1580920 E-06	0.3476563 E+01

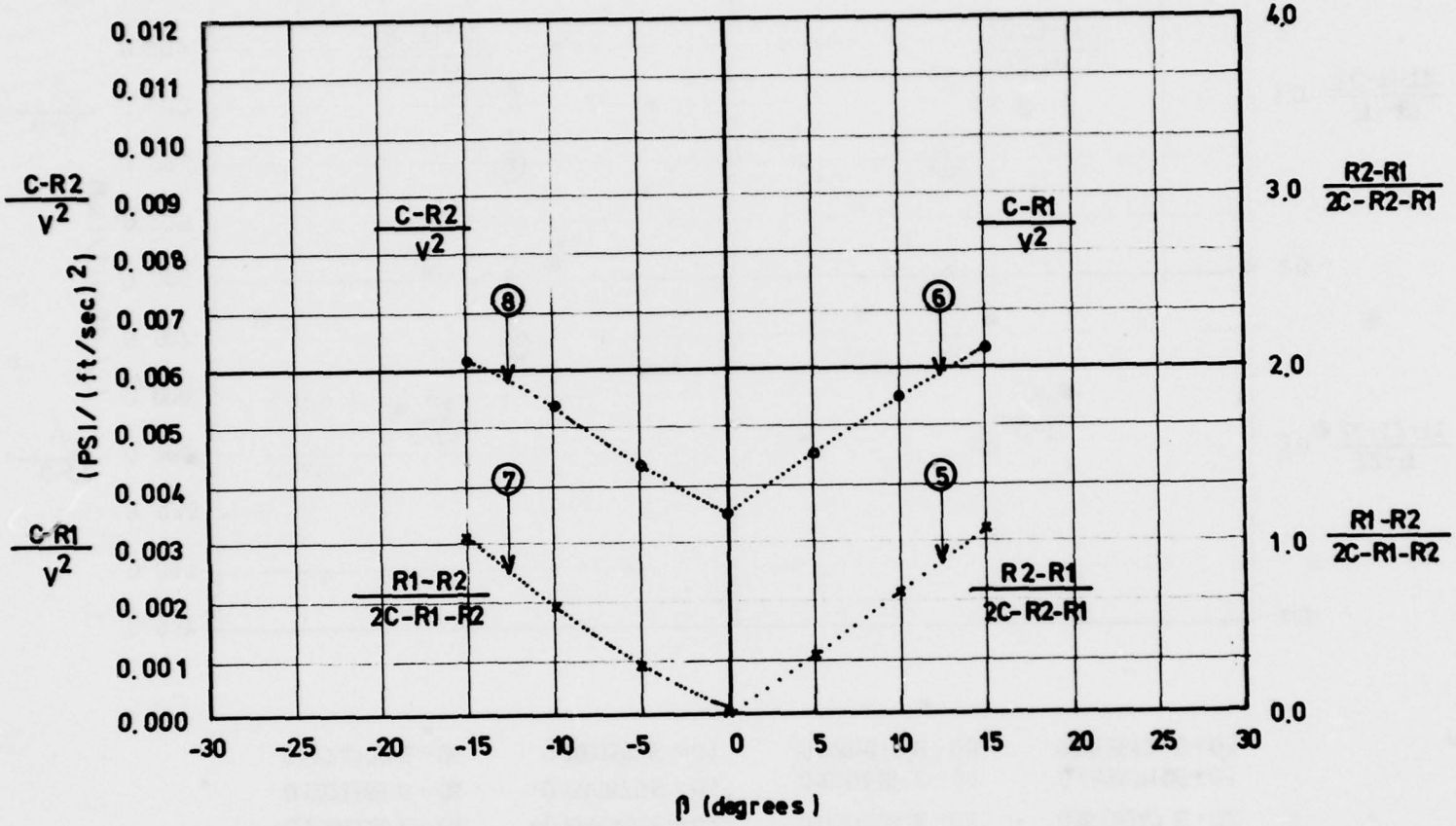


Figure 86 -Post Calibration of Tube 17 in Vertical-Radial Plane

④	③	②	①
0.3319032E-02	0.1096954E+00	0.3318973E-02	-0.1179962E+00
-0.2361536E-03	-0.1556445E+02	0.1497269E-03	0.1678247E+02
-0.1203269E-05	-0.1546875E+01	0.1030415E-04	-0.4136719E+01
0.1774170E-06	0.2601563E+01	-0.5261973E-06	0.1882812E+01

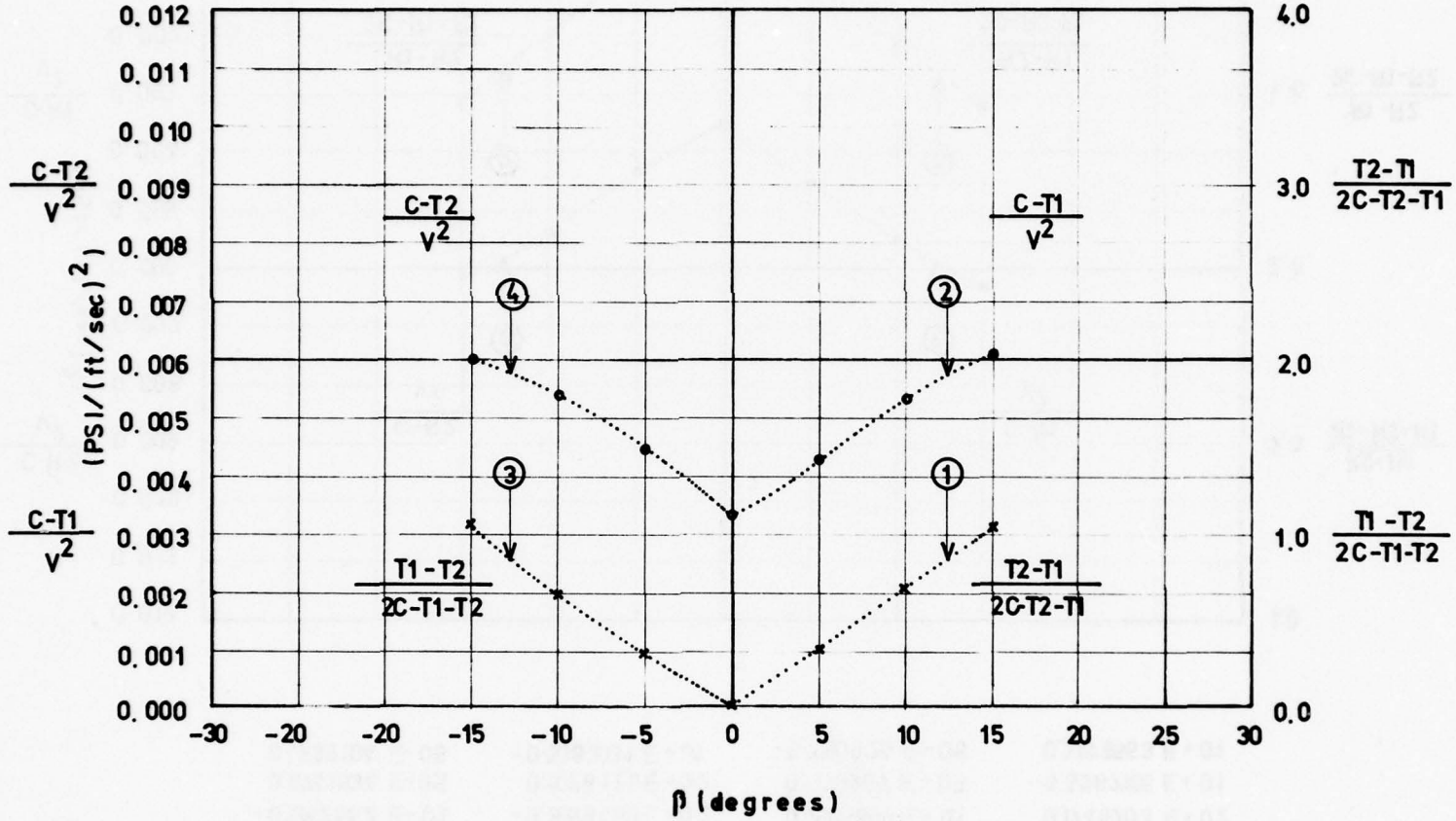


Figure 87 -Post Calibration of Tube 20 in Horizontal-Tangential Plane

⑧ 0.3454018E - 02	⑦ 0.6806030E+00	⑥ 0.3454007 E - 02	⑤ -0.5756531E+00
- 0.9816885E - 04	- 0.2194141 E+02	0.2411604 E - 03	0.1851953 E+02
0.1465529 E - 04	0.1227344 E+02	- 0.8109957E - 05	- 0.8941406 E+01
0.6945338E- 06	- 0.5441406E+01	0.2805609 E - 06	0.5242187 E+01

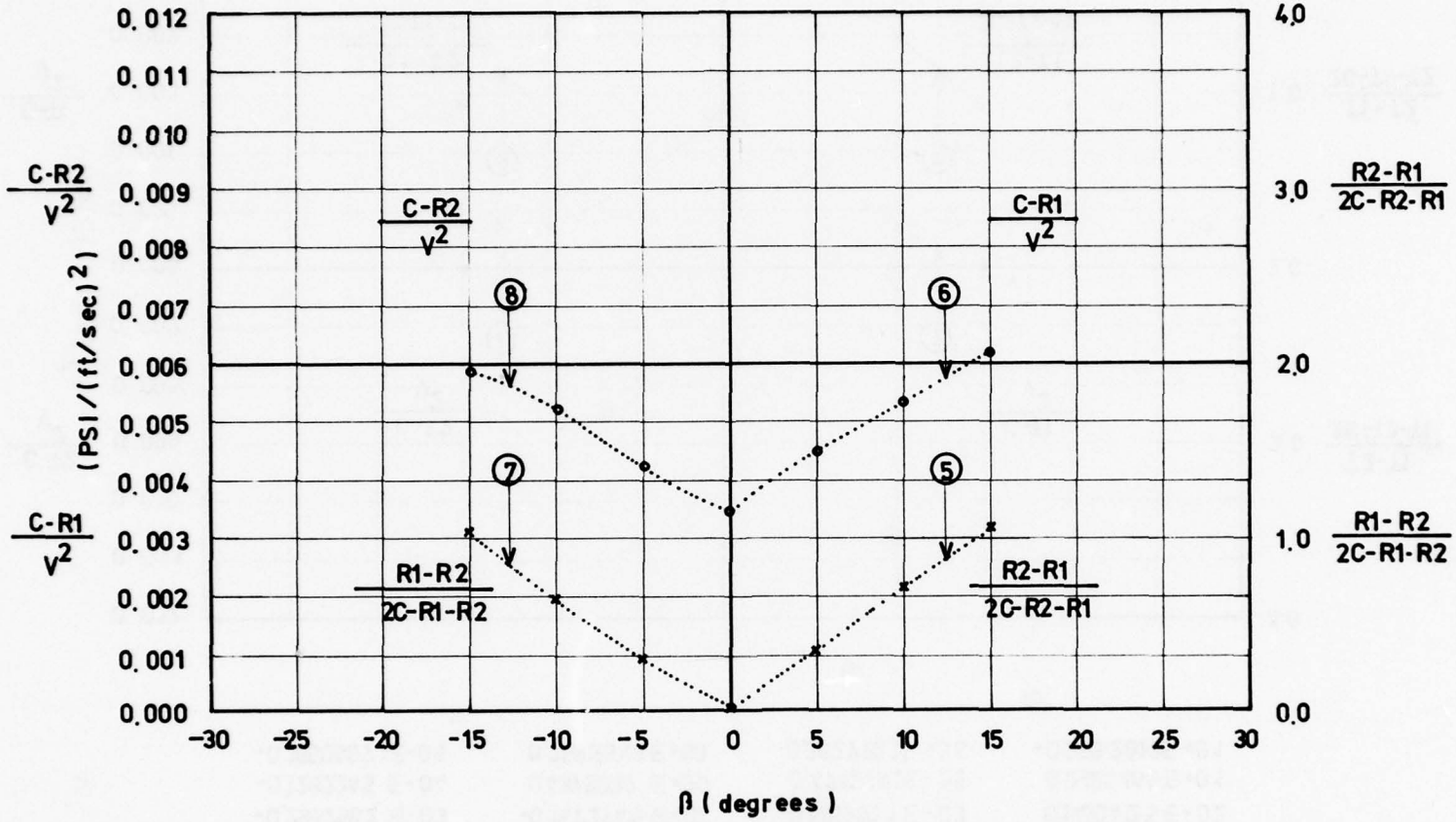


Figure 88 - Post Calibration of Tube 20 in Vertical-Radial Plane

④	③	②	①
0.3225006 E-02	0.6744385 E-01	0.3224976 E-02	-0.6291199 E-01
-0.2957582 E-03	-0.1573145 E+02	0.1959801 E-03	0.1460425 E+02
-0.1282245 E-04	0.4375000 E+00	0.4712492 E-05	0.2480469 E+01
-0.3550667 E-06	0.7695313 E+00	-0.3627501 E-06	-0.2632812 E+01

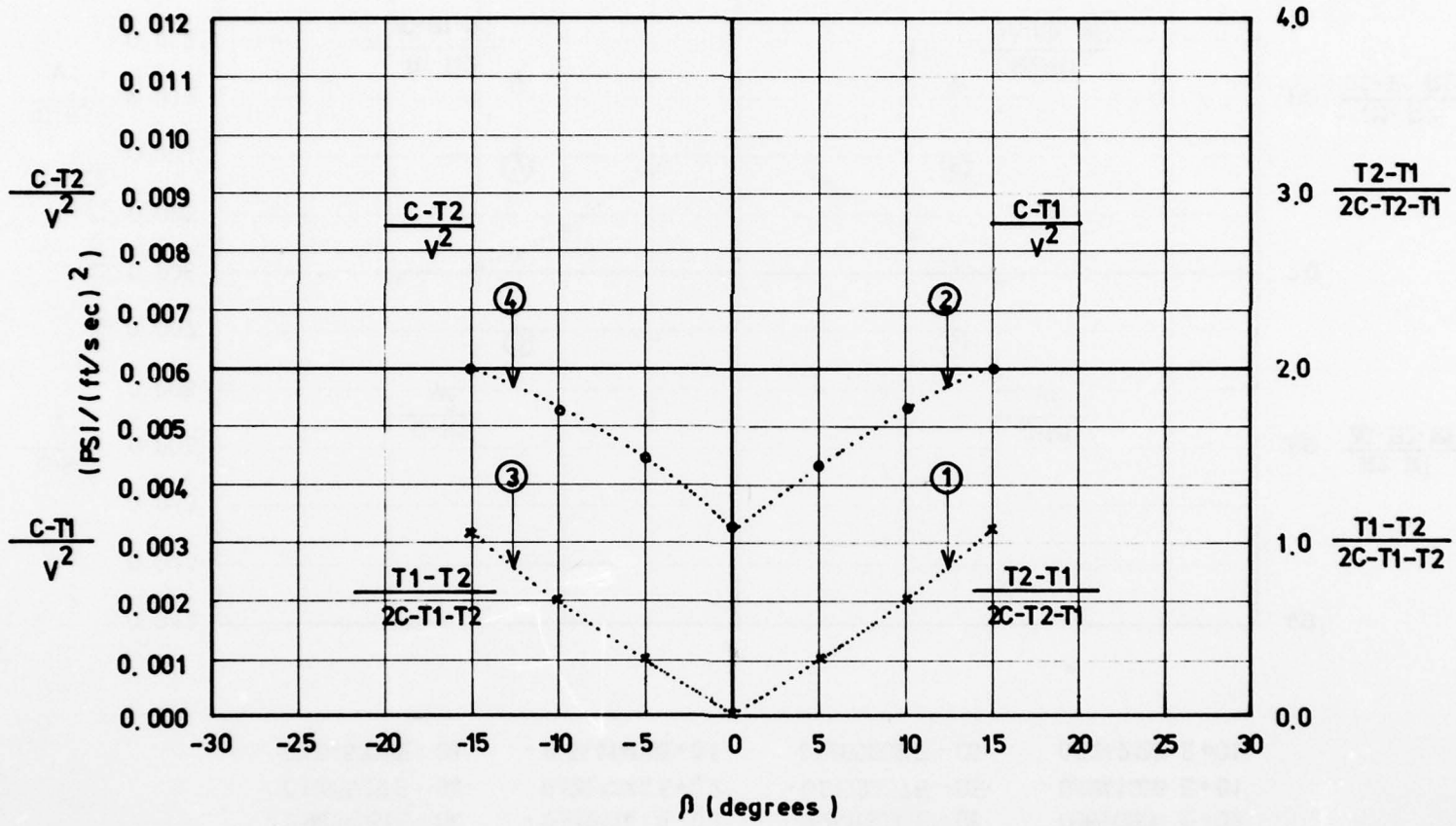


Figure 89 - Post Calibration of Tube 21 in Horizontal-Tangential Plane

⑧ 0.3282003E - 02	⑦ 0.4818878E + 00	⑥ 0.3282055E - 02	⑤ -0.3369751E + 00
-0.2561212E - 03	-0.2027344E + 02	0.2506971E - 03	0.1396875E + 02
-0.9834766E - 05	0.9011719E + 01	-0.5785376E - 05	0.2699219E + 01
-0.2768356E - 06	-0.3484375E + 01	0.7590279E - 07	-0.2218750E + 01

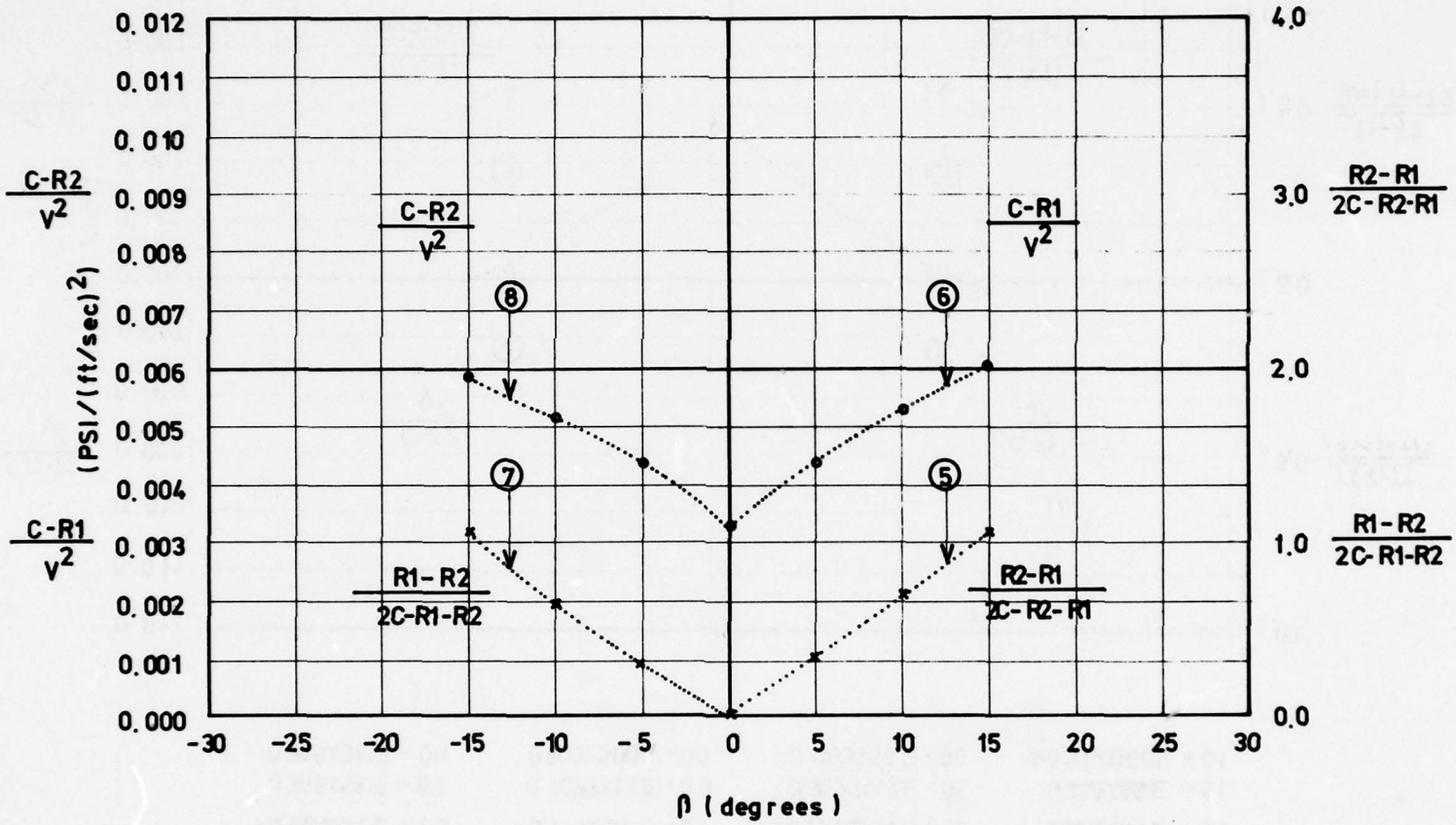


Figure 90 - Post Calibration of Tube 21 in Vertical-Radial Plane

④ 0.3372036E - 02	③ 0.2365417 E +00	② 0.3372021E - 02	① -0.1962574E +00
-0.1891851 E - 03	-0.1654297 E +02	0.2312064 E - 03	0.1380859 E +02
0.3654510E - 05	0.7070313E +00	-0.5029142E - 06	0.4054688E +01
0.3094319E - 06	0.9062500E +00	-0.1583366 E - 06	-0.3128906E +01

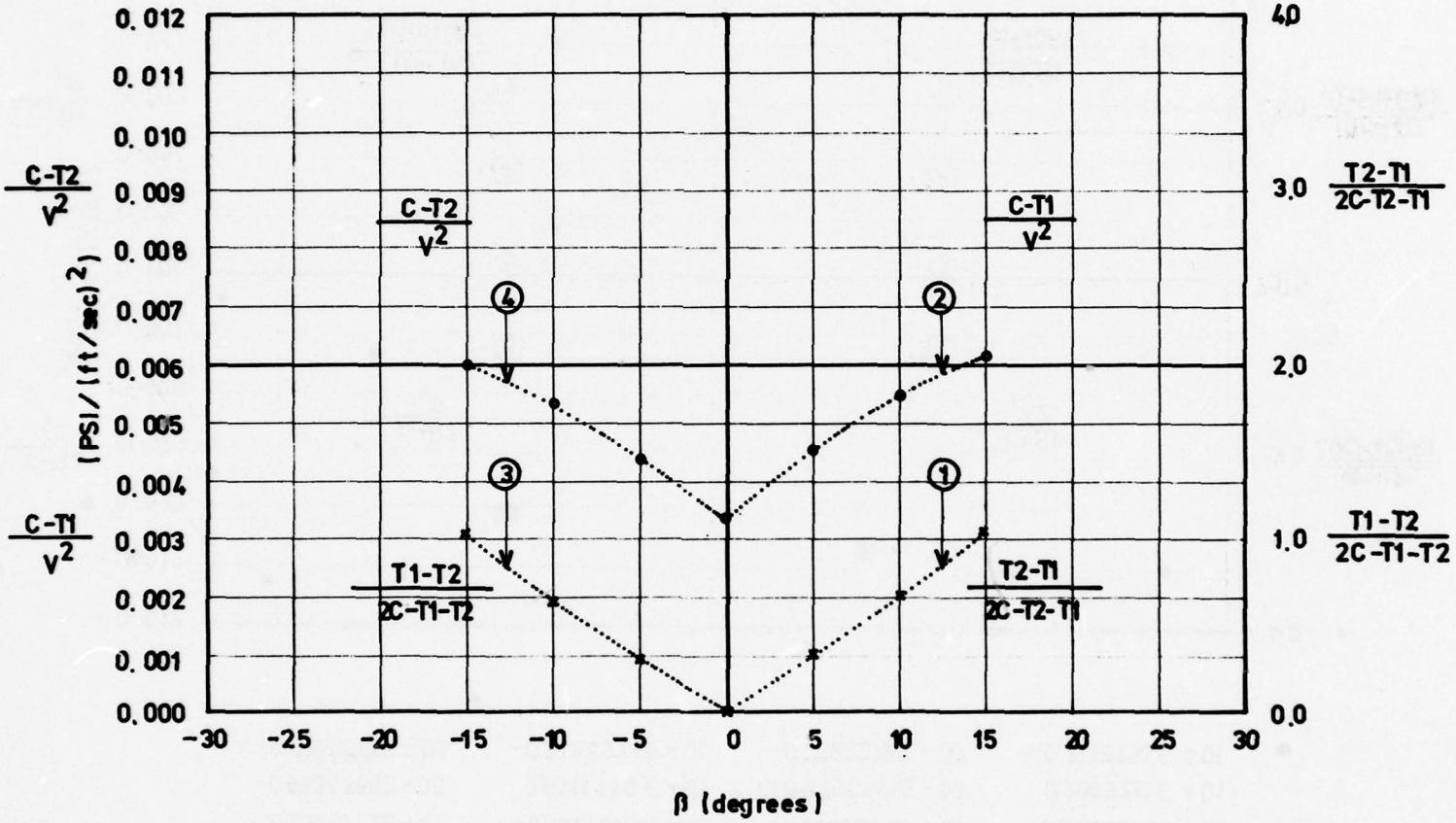


Figure 91 -Post Calibration of Tube 22 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3377978 E - 02	0.5030518 E +00	0.3378034 E - 02	-0.3744659 E +00
-0.1605153 E - 03	-0.2156641 E +02	0.2316833 E - 03	0.1585938 E +02
0.4366040 E - 05	0.1273828 E +02	-0.6418675 E - 05	-0.1601563 E +01
0.2582092 E - 06	-0.6167969 E +01	0.2025627 E - 06	0.1484375 E +00

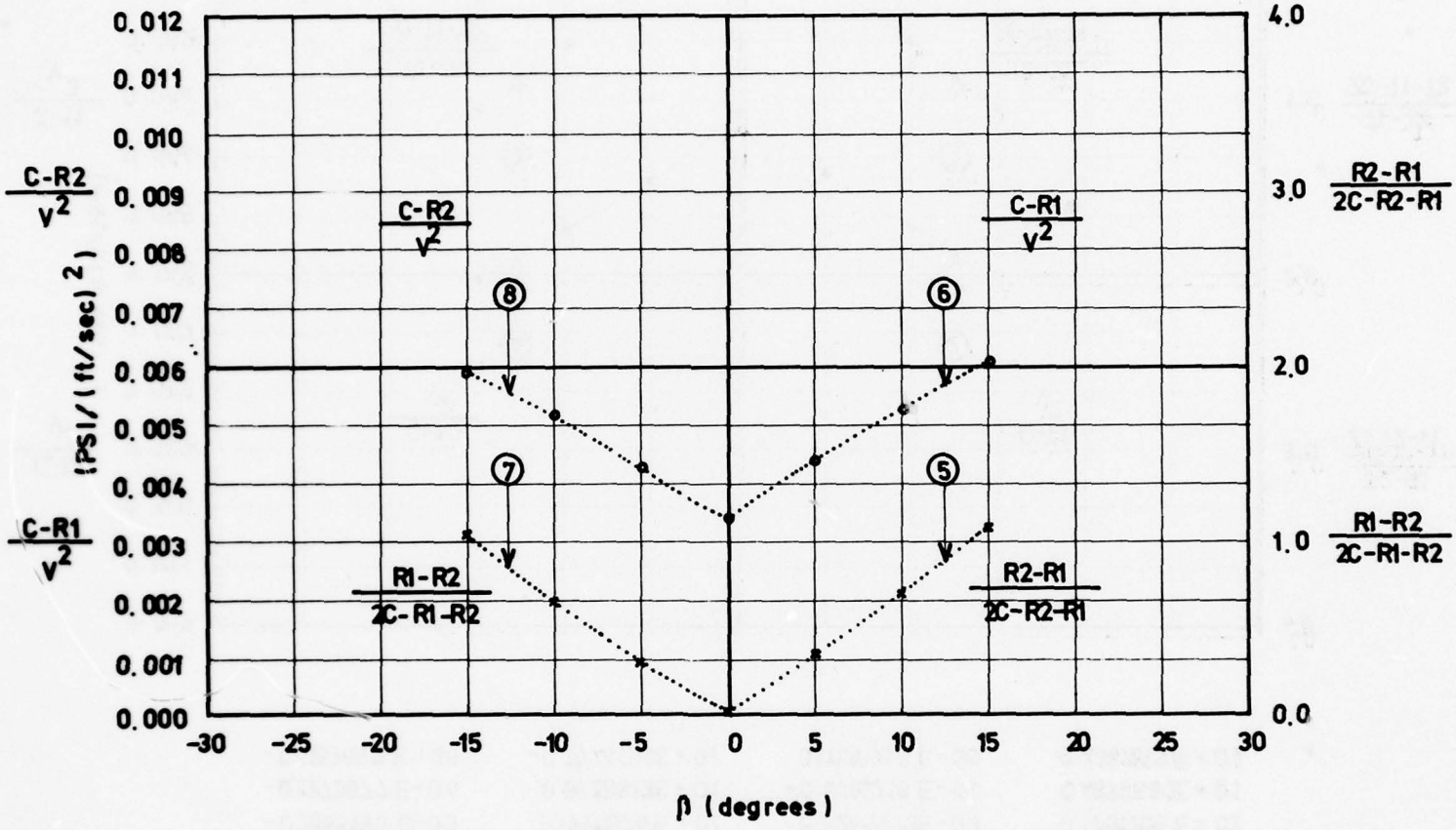


Figure 92 -Post Calibration of Tube 22 in Vertical-Radial Plane

④	③	②	①
0.3229037 E-02	0.1452179 E+00	0.3229026 E-02	-0.1476288 E+00
-0.2865195 E-03	-0.1720025 E+02	0.2265573 E-03	0.1751709 E+02
-0.1273677 E-04	0.5820313 E+01	-0.4716218 E-05	-0.4976562 E+01
-0.4167669 E-06	-0.3074219 E+01	0.1159497 E-06	0.2382813 E+01

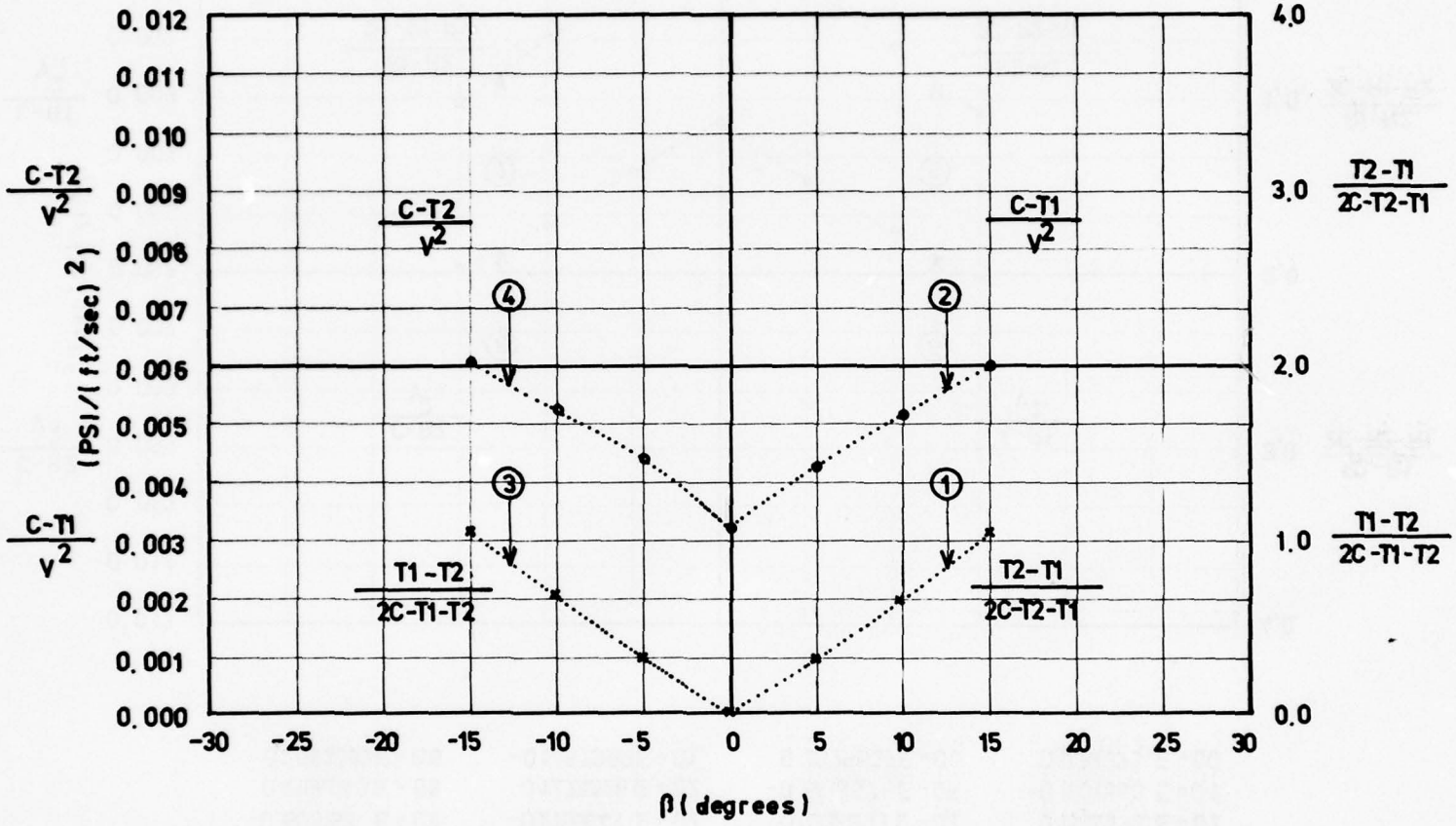


Figure 93 -Post Calibration of Tube 23 in Horizontal-Tangential Plane

⑧ 0.3362060E-02	⑦ 0.3827515E+00	⑥ 0.3362071E-02	⑤ -0.2873230E+00
-0.2024174E-03	-0.2101465E+02	0.1674294E-03	0.1560547E+02
-0.1907349E-05	0.1395703E+02	0.1129881E-04	-0.9862813E+00
-0.1234002E-07	-0.7730469E+01	-0.6963965E-06	-0.6640625E-01

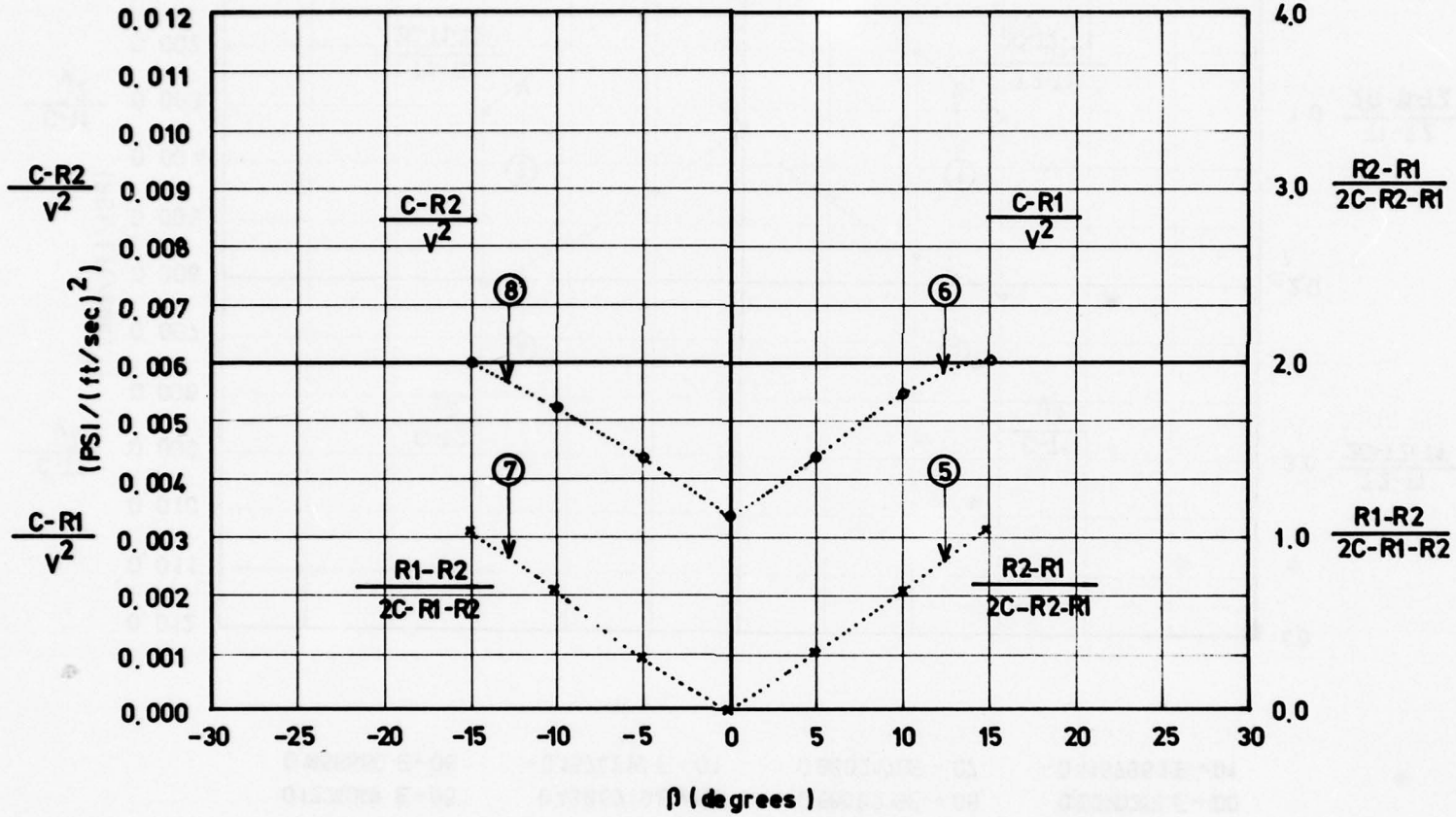


Figure 94 -Post Calibration of Tube 23 in Vertical-Radial Plane

④ 0.3338020 E-02	③ 0.1430206 E+00	② 0.3337968 E-02	① -0.1232605 E+00
-0.2050996 E-03	-0.1737769 E+02	0.2729297 E-03	0.1490845 E+02
0.1274049 E-05	0.4386719 E+01	-0.6899238 E-05	0.9570313 E+00
0.1855660 E-06	-0.1574219 E+01	0.9802170 E-07	-0.1167969 E+01

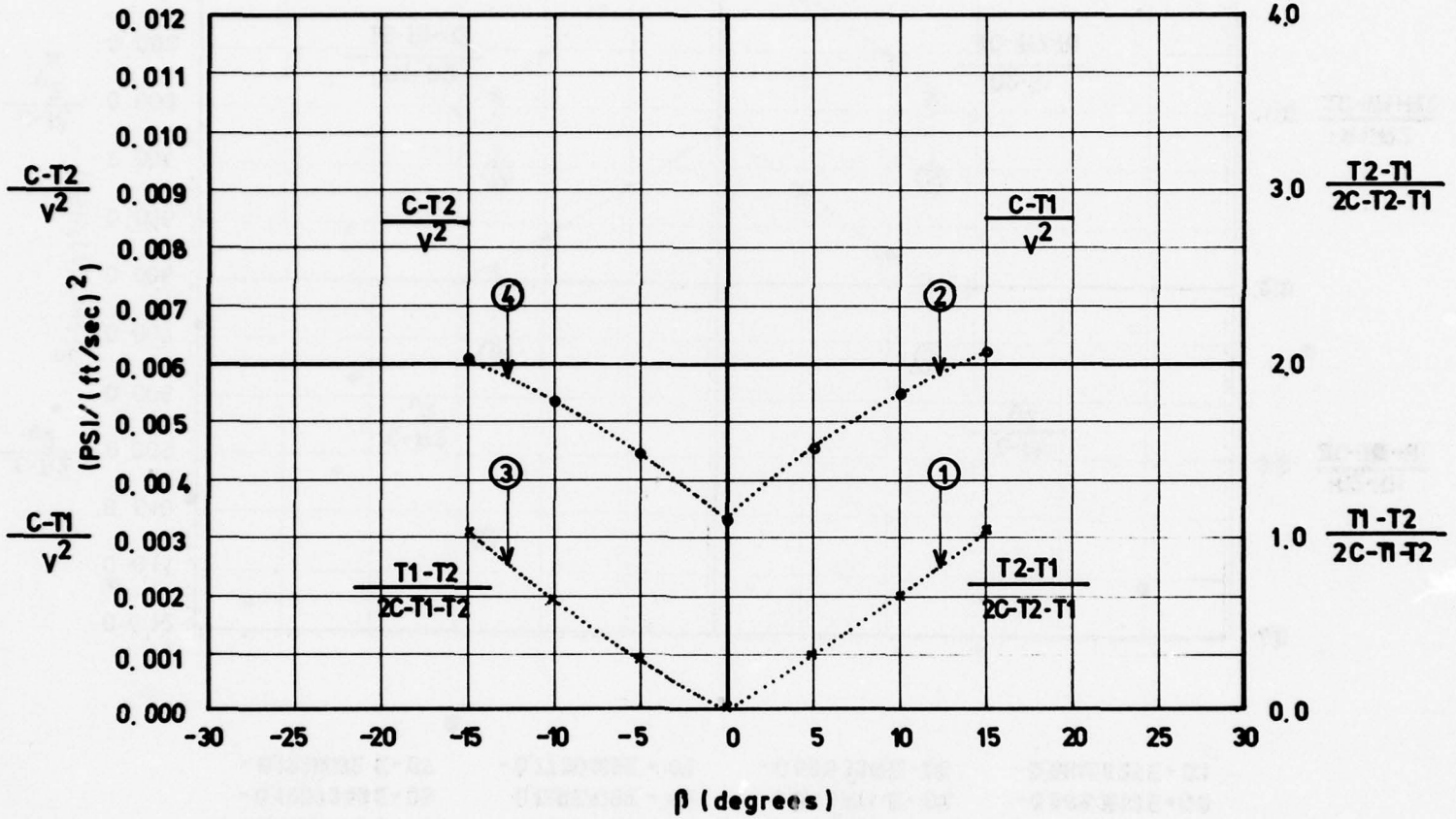


Figure 95 -Post Calibration of Tube 24 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3366038 E-02	0.2098541 E+00	0.3366001 E-02	-0.1725006 E+00
-0.2425313 E-03	-0.1820508 E+02	0.1923442E-03	0.1491406 E+02
-0.8150935E-05	0.7207031E+01	0.5427748E-05	0.2460938E+00
-0.2889428 E-06	-0.3718750 E+01	-0.4014000E-06	-0.8867188 E+00

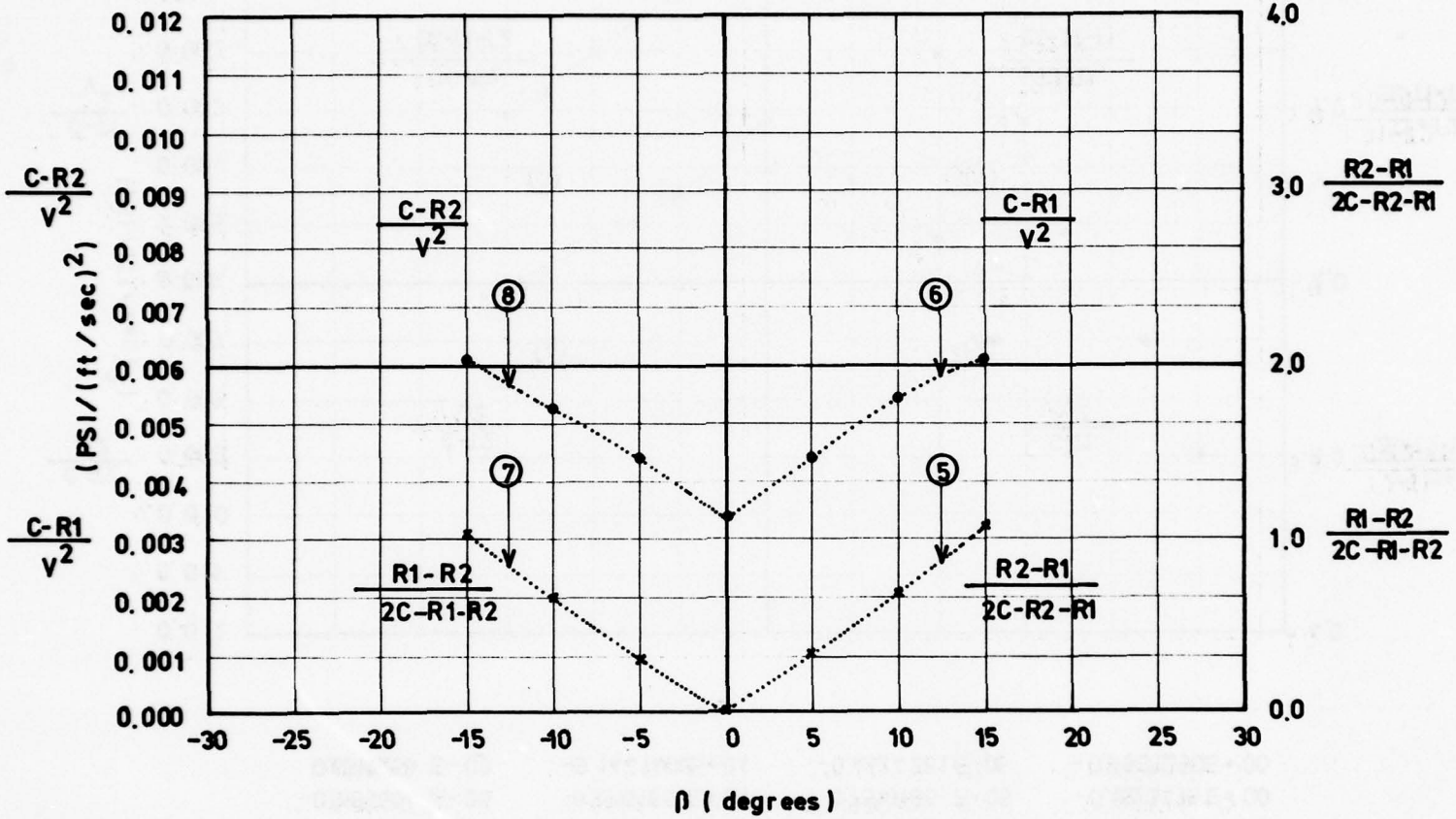


Figure 96 -Post Calibration of Tube 24 in Vertical-Radial Plane

④ 0.3226016 E-02	③ 0.1494751 E+00	② 0.3226057 E-02	① -0.1354065 E+00
-0.2623200 E-03	-0.1706836 E+02	0.1761913 E-03	0.1542603 E+02
-0.5185604 E-05	0.3910156 E+01	0.7510185 E-05	-0.1523438 E+00
0.6519258 E-08	-0.1441406 E+01	-0.4824251 E-06	-0.9531250 E+00

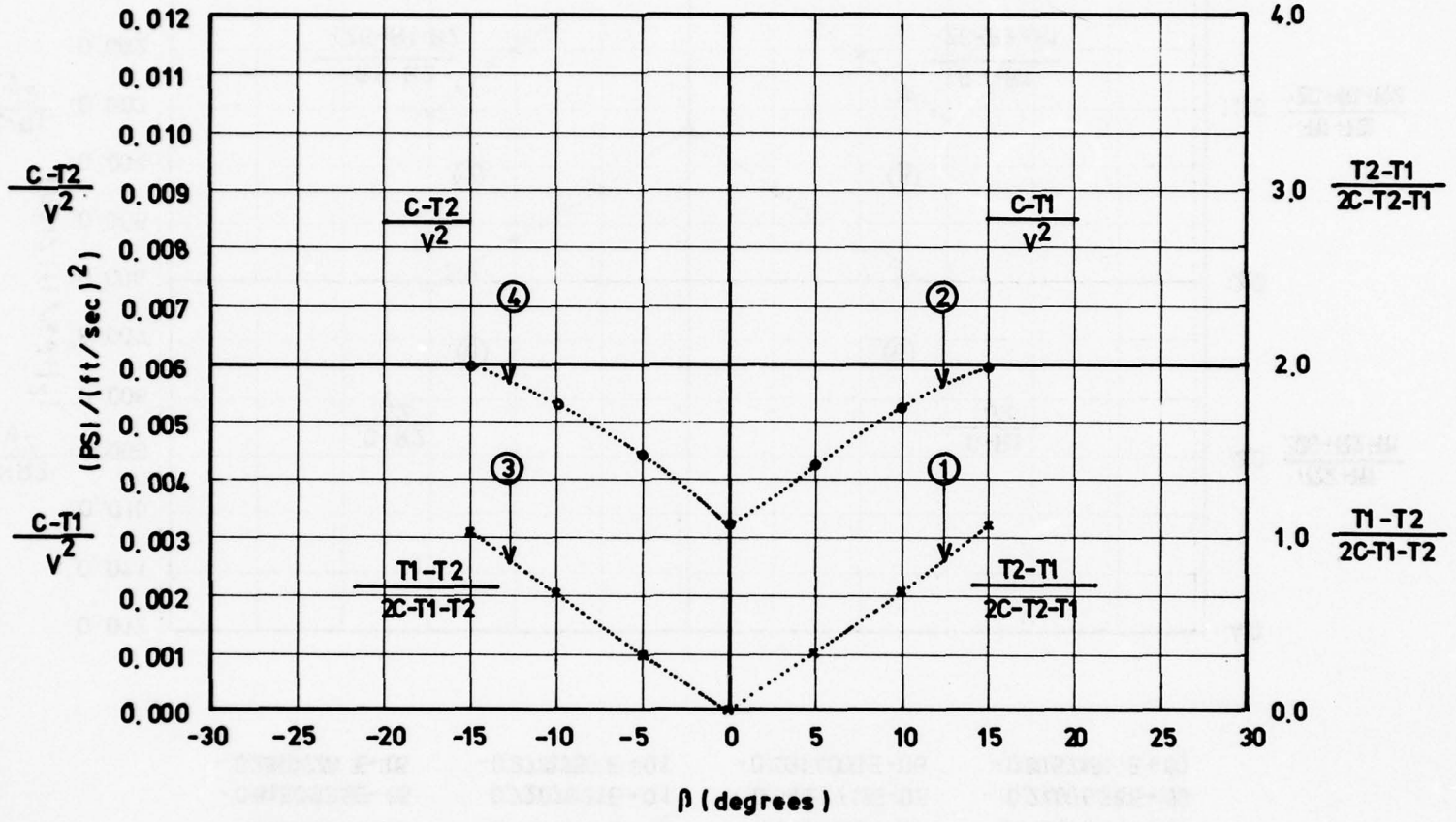


Figure 97 - Post Calibration of Tube 26 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3288947 E-02	0.2699585E+00	0.3289118E-02	-0.2454987E+00
-0.1398921 E-03	-0.1673437 E+02	0.2851486E-03	0.1520703E+02
0.9998679E-05	0.2070313E+01	-0.1734868E-04	-0.1714844 E+01
0.5275942E-06	-0.1601563 E+00	0.7287599E-06	0.1000000 E+01

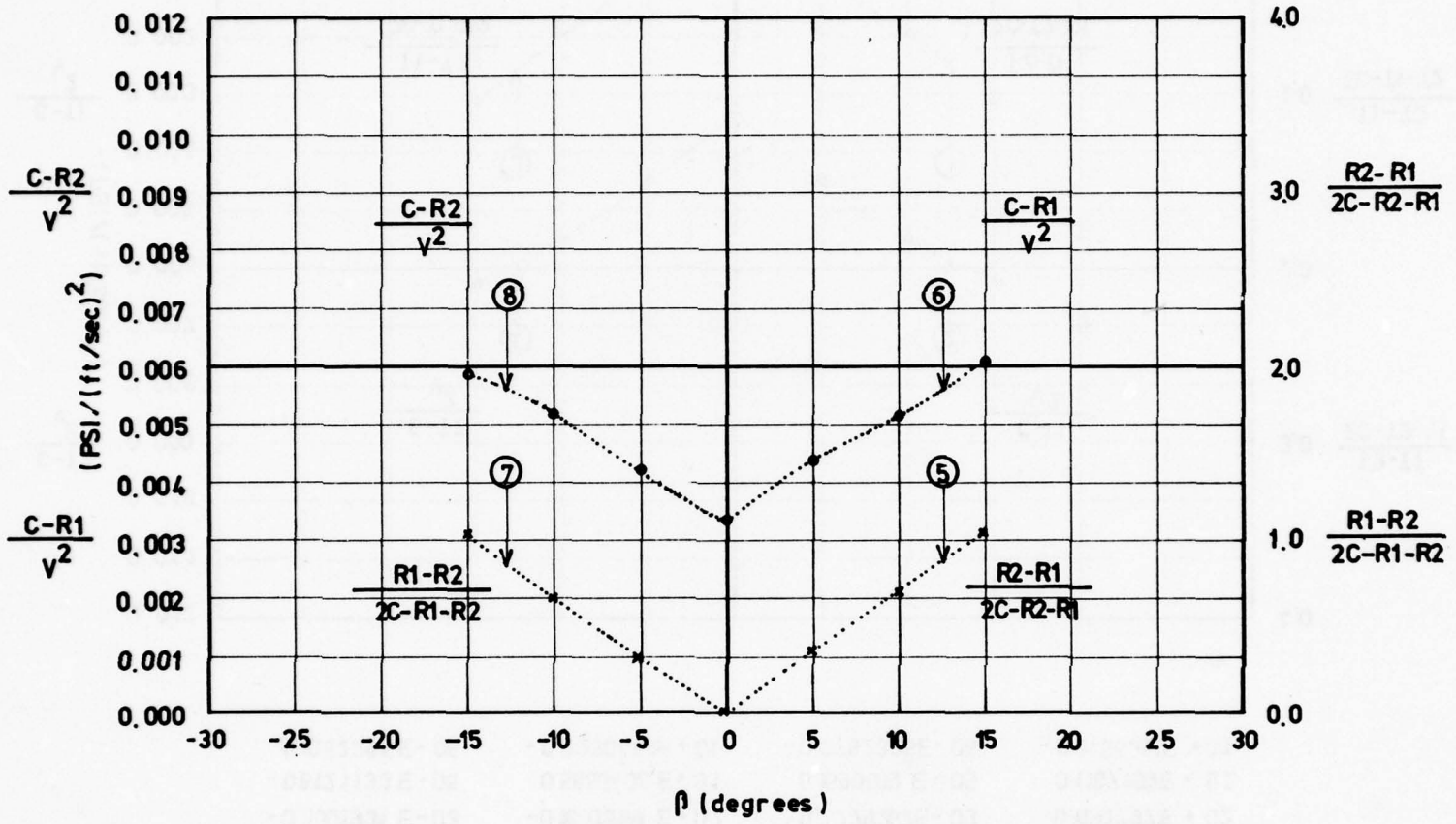


Figure 98 -Post Calibration of Tube 26 in Vertical-Radial Plane

④	③	②	①
0.3362894E-02	0.1412506E+00	0.3363017E-02	-0.9454346E-01
-0.2301931E-03	-0.1800659E+02	0.2279282E-03	0.1191797E+02
-0.8121133E-06	0.5566406E+01	0.1590699E-05	0.1187109E+02
0.1052395E-06	-0.2230469E+01	-0.2782326E-06	-0.9156250E+01

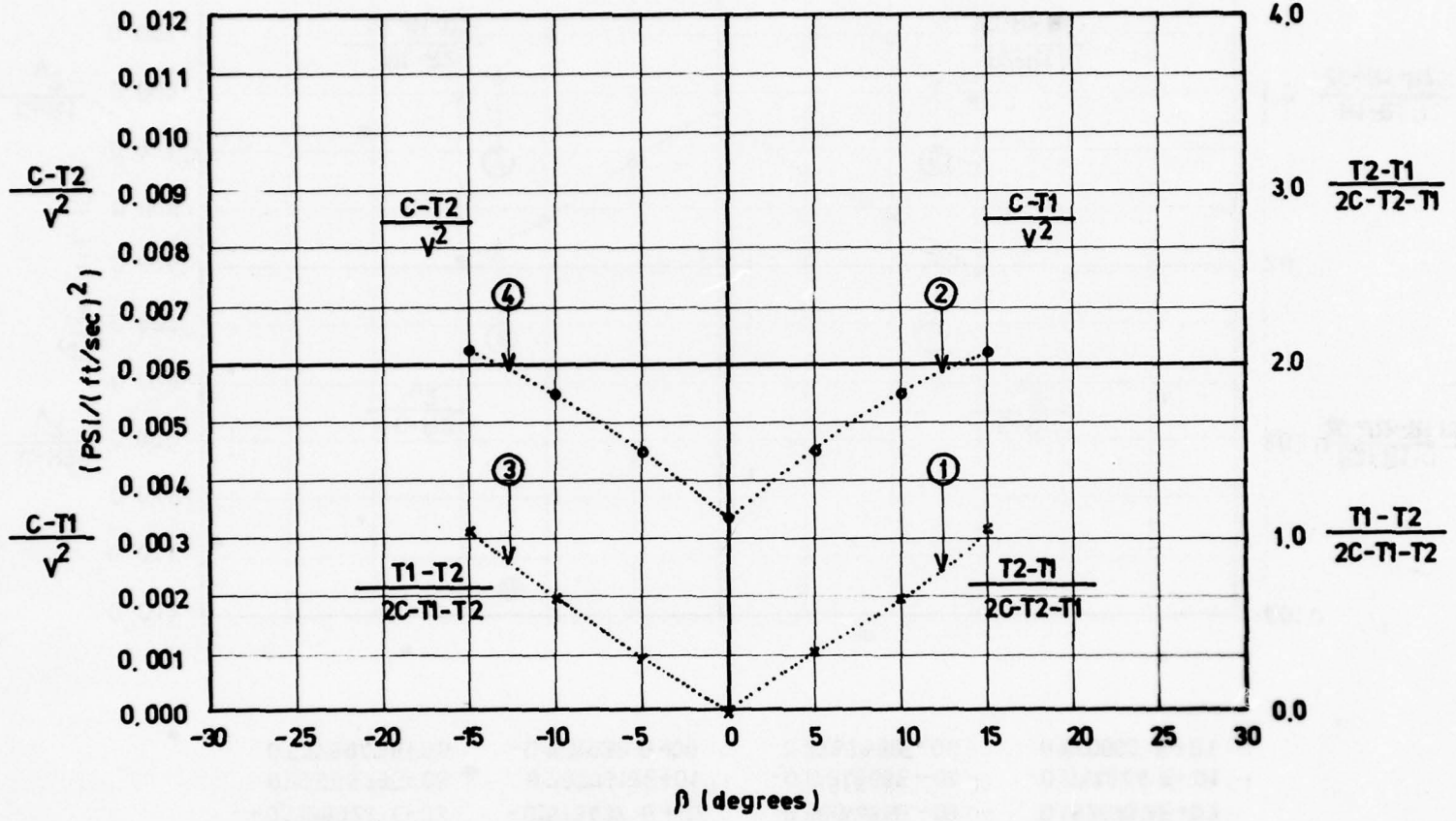


Figure 99 -Post Calibration of Tube 27 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3547993 E - 02	0.6817627 E - 01	0.3548000 E - 02	-0.5364990 E - 01
-0.1334548 E - 03	-0.1580957 E + 02	0.1609325 E - 03	0.1237500 E + 02
0.1590326 E - 04	-0.1640625 E + 01	0.8594245 E - 05	0.8812500 E + 01
0.8540228 E - 06	0.2937500 E + 01	-0.5026814 E - 06	-0.6562500 E + 01

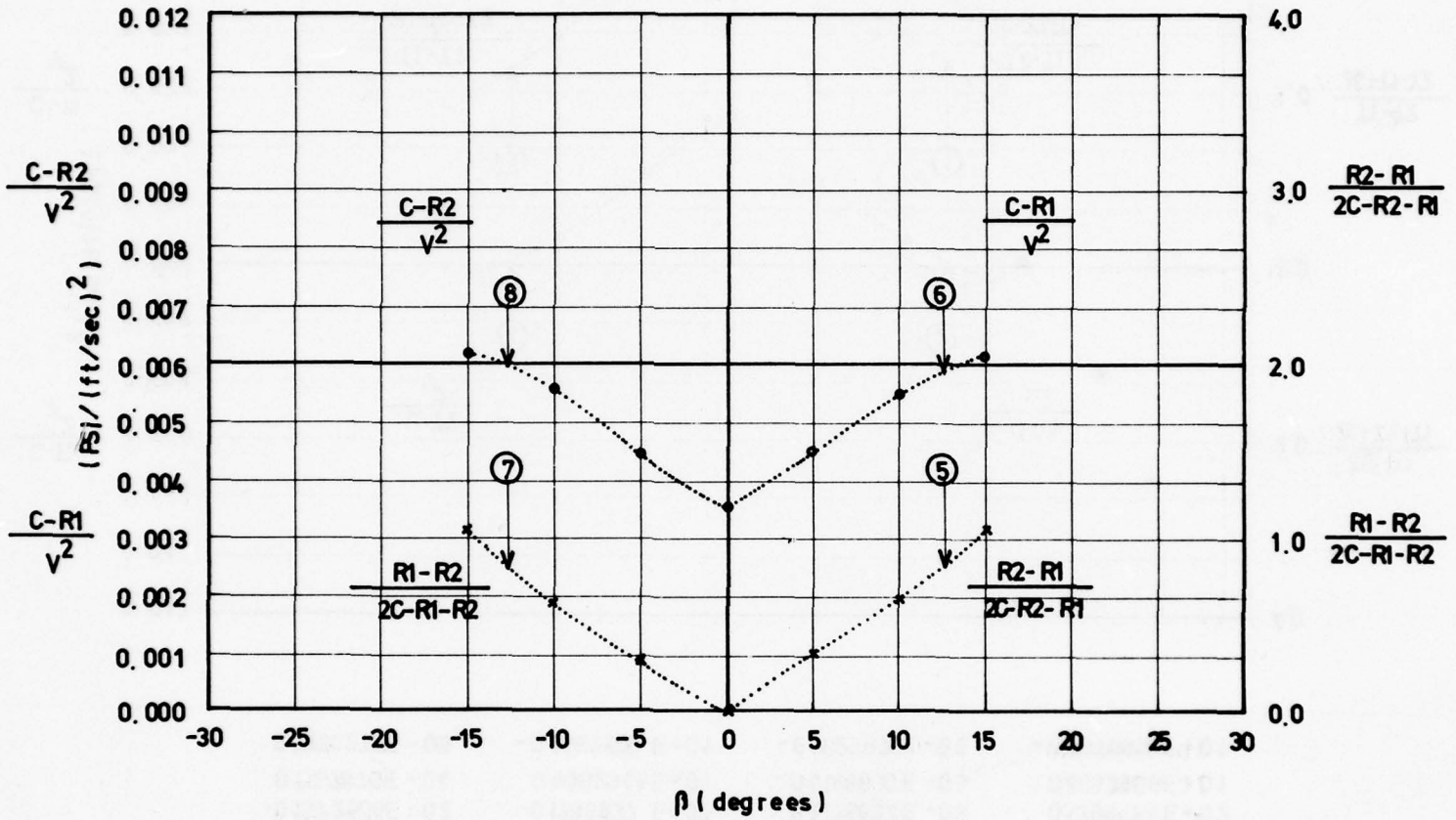


Figure 100 -Post Calibration of Tube 27 in Vertical-Radial Plane

④ 0.3415003E-02	③ 0.8720398E-01	② 0.3414944E-02	①-0.6858826E-01
-0.1672506E-03	-0.1785937 E+02	0.2135634E-03	0.1399976 E+02
0.1167879E-04	0.6902344E+01	0.4168600 E-05	0.4003906E+01
0.7136259E-06	-0.3687500 E+01	-0.4027970E-06	-0.3375000E+01

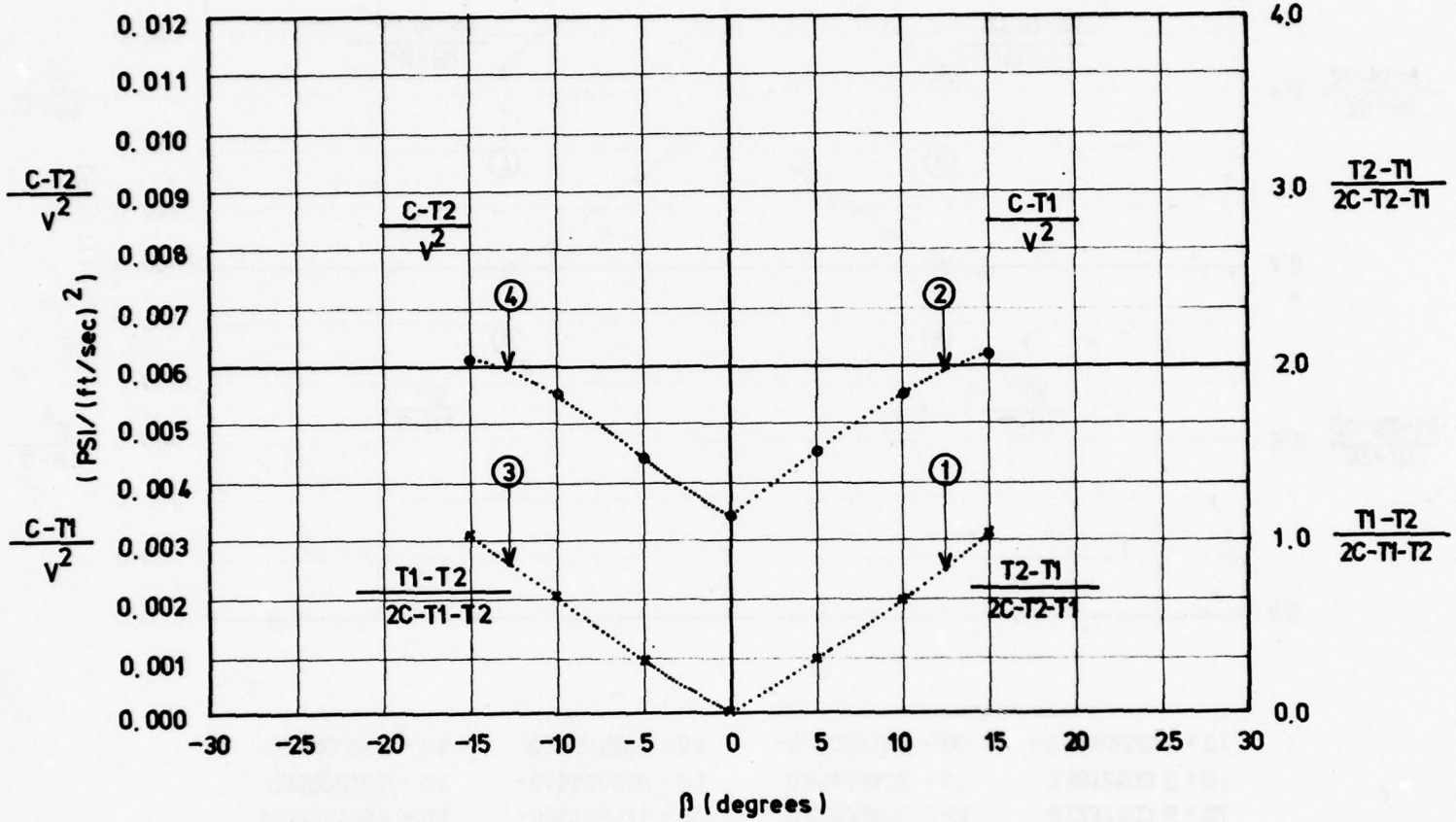


Figure 101 -Post Calibration of Tube 28 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3451966E-02	0.3559113E+00	0.3451947E-02	-0.2603149 E+00
-0.2017617 E-03	-0.1932422E+02	0.1821518 E-03	0.1396484 E+02
-0.1460314 E-05	0.6566406E+01	0.7539988 E-05	0.4179688 E+01
-0.2351590 E-07	-0.2273437E+01	-0.5101319 E-06	-0.3578125 E+01

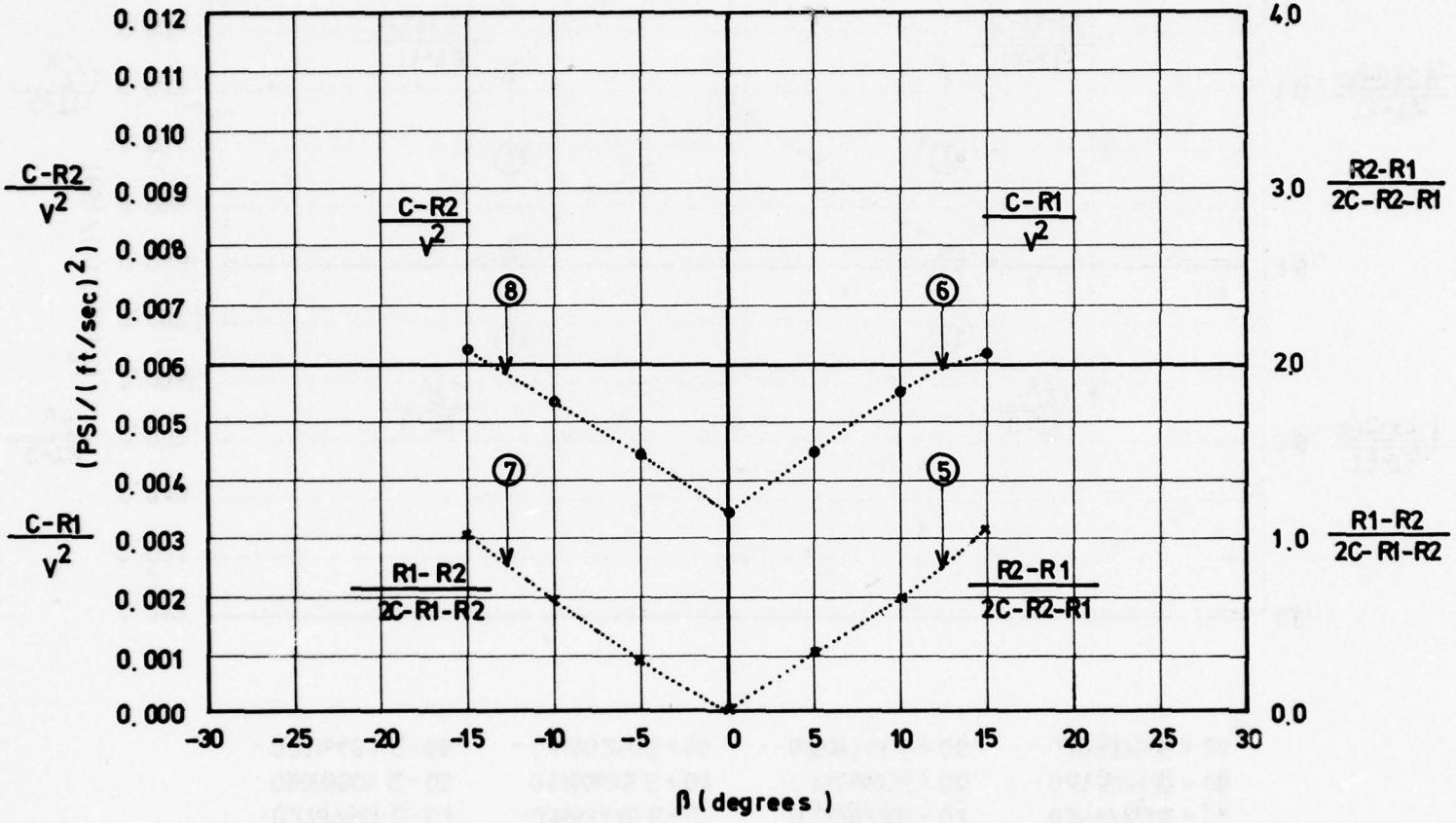


Figure 102 -Post Calibration of Tube 28 in Vertical-Radial Plane

④	③	②	①
0.3160015 E-02	0.5210876E-01	0.3160007 E-02	-0.5247498E-01
-0.2737641 E-03	-0.1551440 E+02	0.2226233E-03	0.1567163 E+02
08888543 E-05	0.1390625 E+01	-0.1564622E-06	-0.61 32813E+00
-0.2116431 E-06	-0.1406250E+00	-0.1508743 E-06	-0.6093750E+00

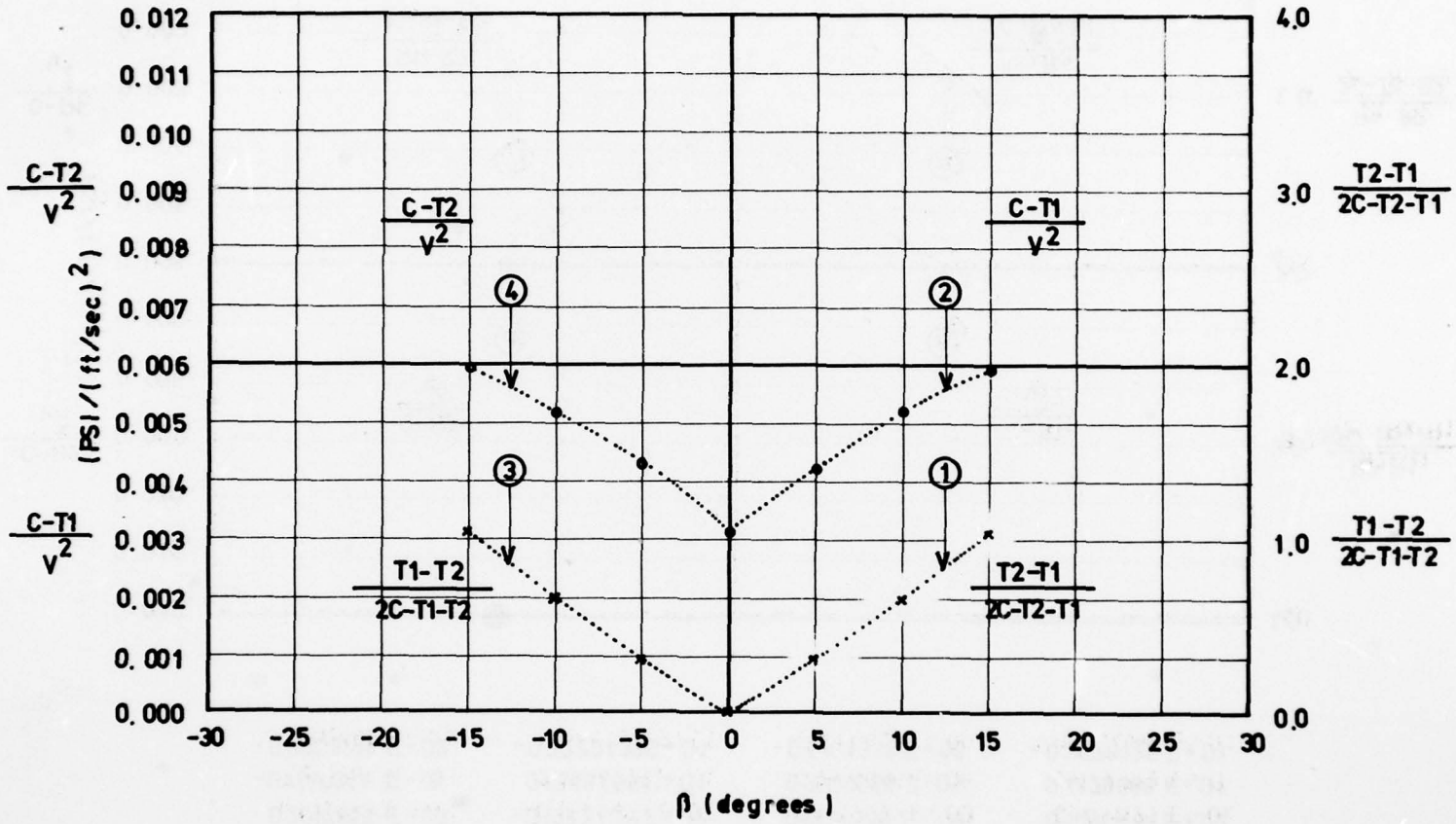


Figure 103 -Post Calibration of Tube 29 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3540050E-02	0.4019012E+00	0.3540065E-02	-0.3184967E+00
-0.1351833E-03	-0.1844922E+02	0.1119971E-03	0.1451172E+02
0.3110617E-05	0.4734375E+01	0.9559095E-05	0.1324219E+01
0.1315493E-06	-0.1164063E+01	-0.4197937E-06	-0.1554688E+01

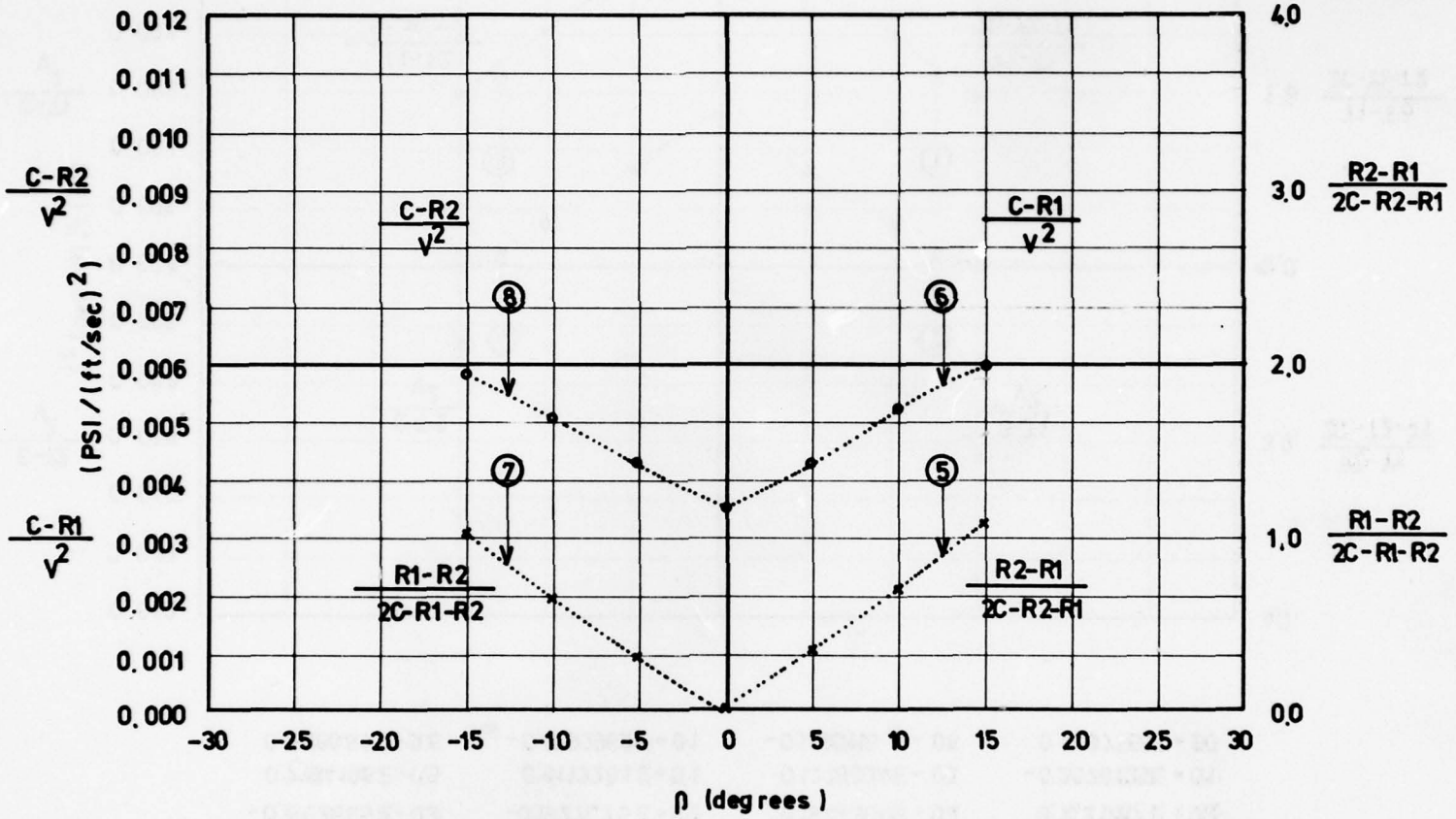


Figure 104 - Post Calibration of Tube 29 in Vertical - Radial Plane

④	③	②	①
0.3344033E-02	0.1802521E+00	0.3344018E-02	-0.1530457E+00
-0.1862645E-03	-0.1927075E+02	0.1944304E-03	0.1631787E+02
0.2194196E-05	0.9113281E+01	0.1270324E-05	-0.2078125E+01
0.1608860E-06	-0.4792969E+01	-0.1490116E-06	0.4687500E+00

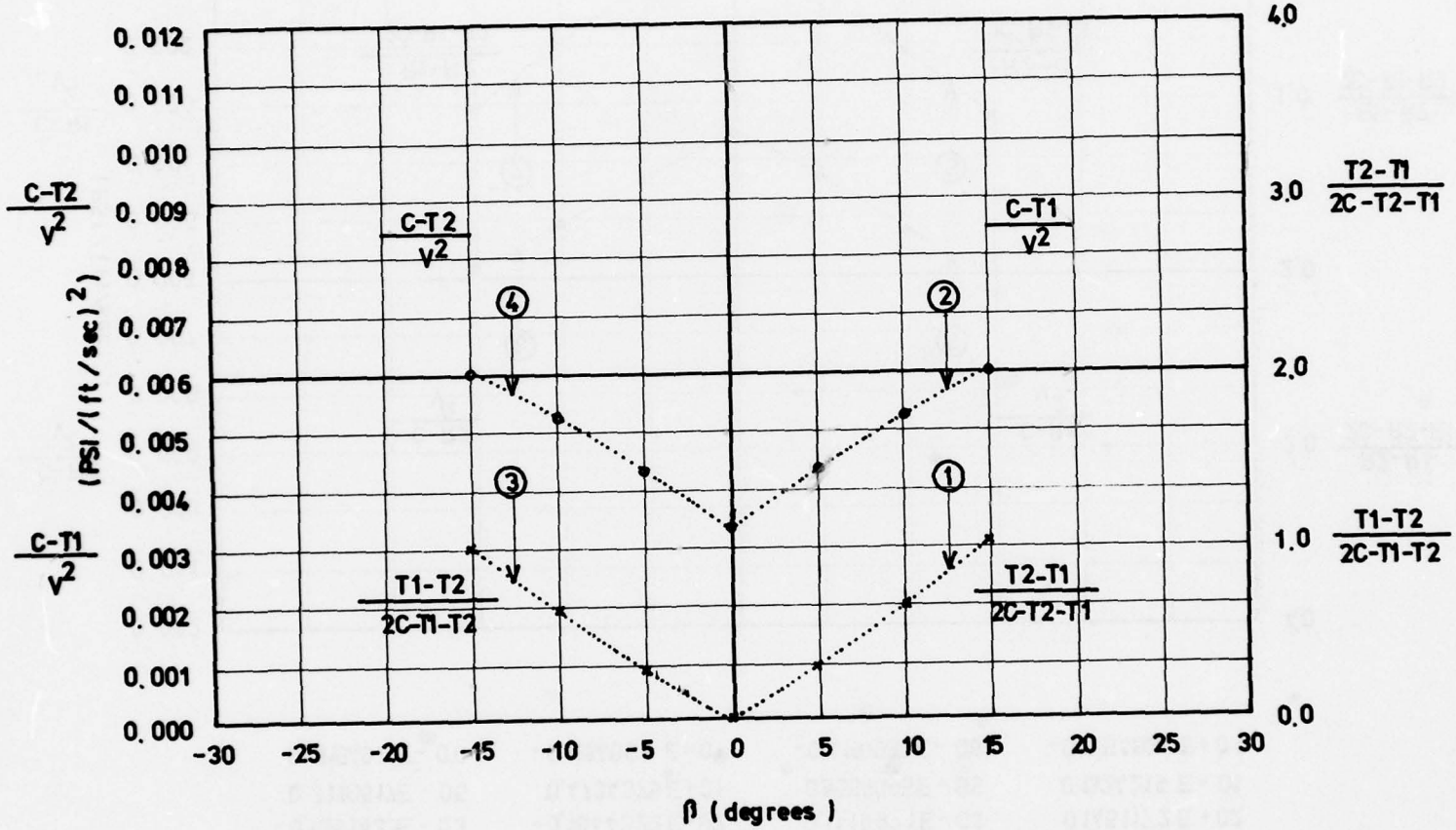


Figure 105 -Post Calibration of Tube 30 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3375027 E-02	0.7976074 E+00	0.3375027E-02	-0.6350098 E+00
-0.1294613 E-03	-0.2009766 E+02	0.2075434E-03	0.1594922E+02
0.1100078 E-04	0.3113281 E+01	0.1300126 E-05	-0.1144531E+01
0.5816109 E-06	0.1363281 E+01	-0.1851004 E-06	0.5468750E-01

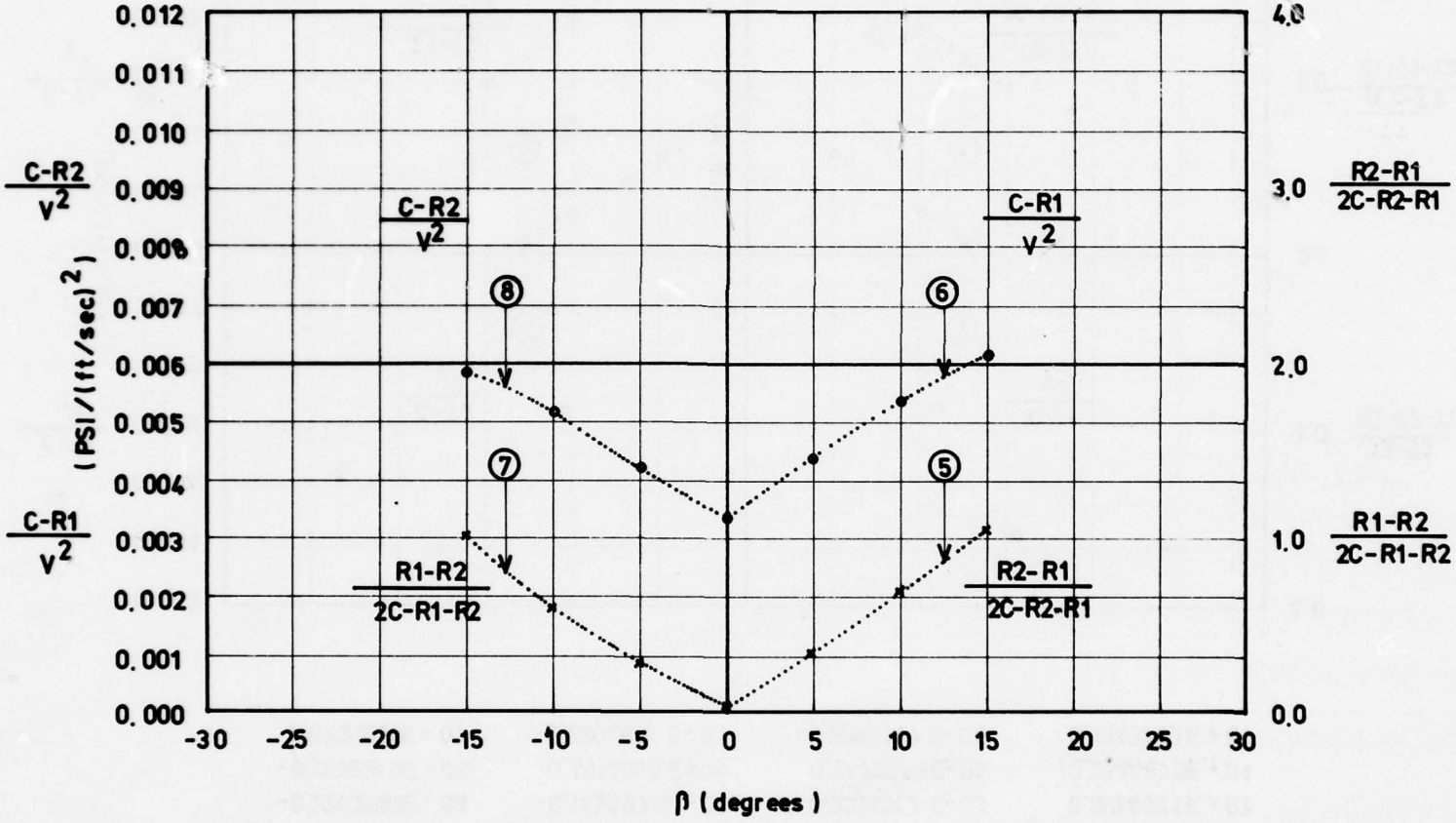


Figure 106 -Post Calibration of Tube 30 in Vertical-Radial Plane

④	③	②	①
0.3216010E-02	0.4351807E-01	0.3216002E-02	-0.3964233E-01
-0.2262592E-03	-0.1736670E+02	0.2003312 E-03	0.1594971E+02
-0.1735985E-05	0.4914063 E+01	0.2473593E-05	-0.2546875E+01
0.6728806E-07	-0.2304688 E+01	-0.2093147 E-06	0.1343750 E+01

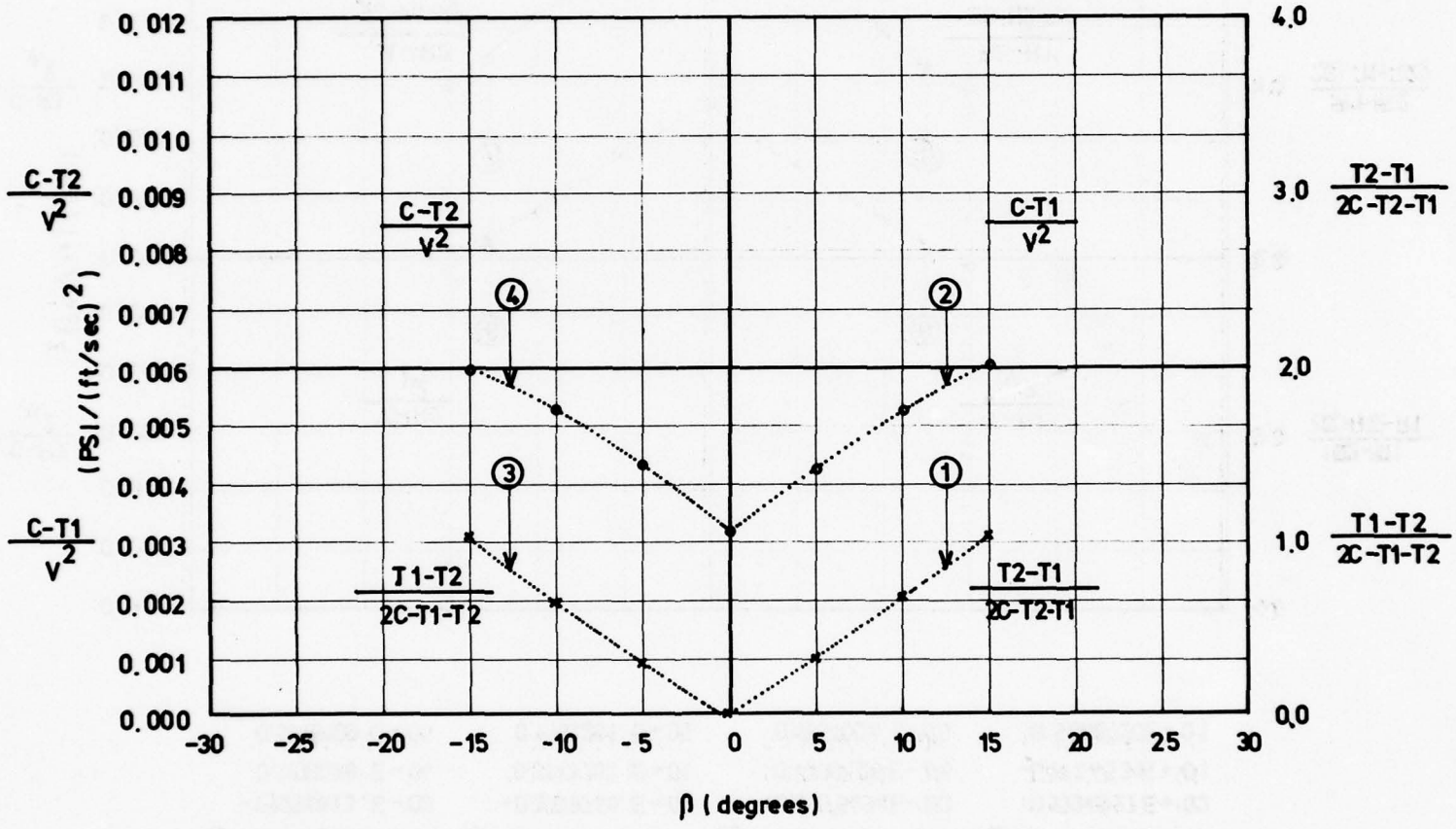


Figure 107 - Post Calibration of Tube 31 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3297005E-02	0.4168243E+00	0.3297005E-02	-0.3989563E+00
-0.1279712E-03	-0.1752344E+02	0.2727509E-03	01676562E+02
0.1314655E-04	0.2195312E+01	-0.1224875E-04	-0.2484375E+01
0.6663613E-06	0.2851563E+00	0.4137401E-06	0.4101563E+00

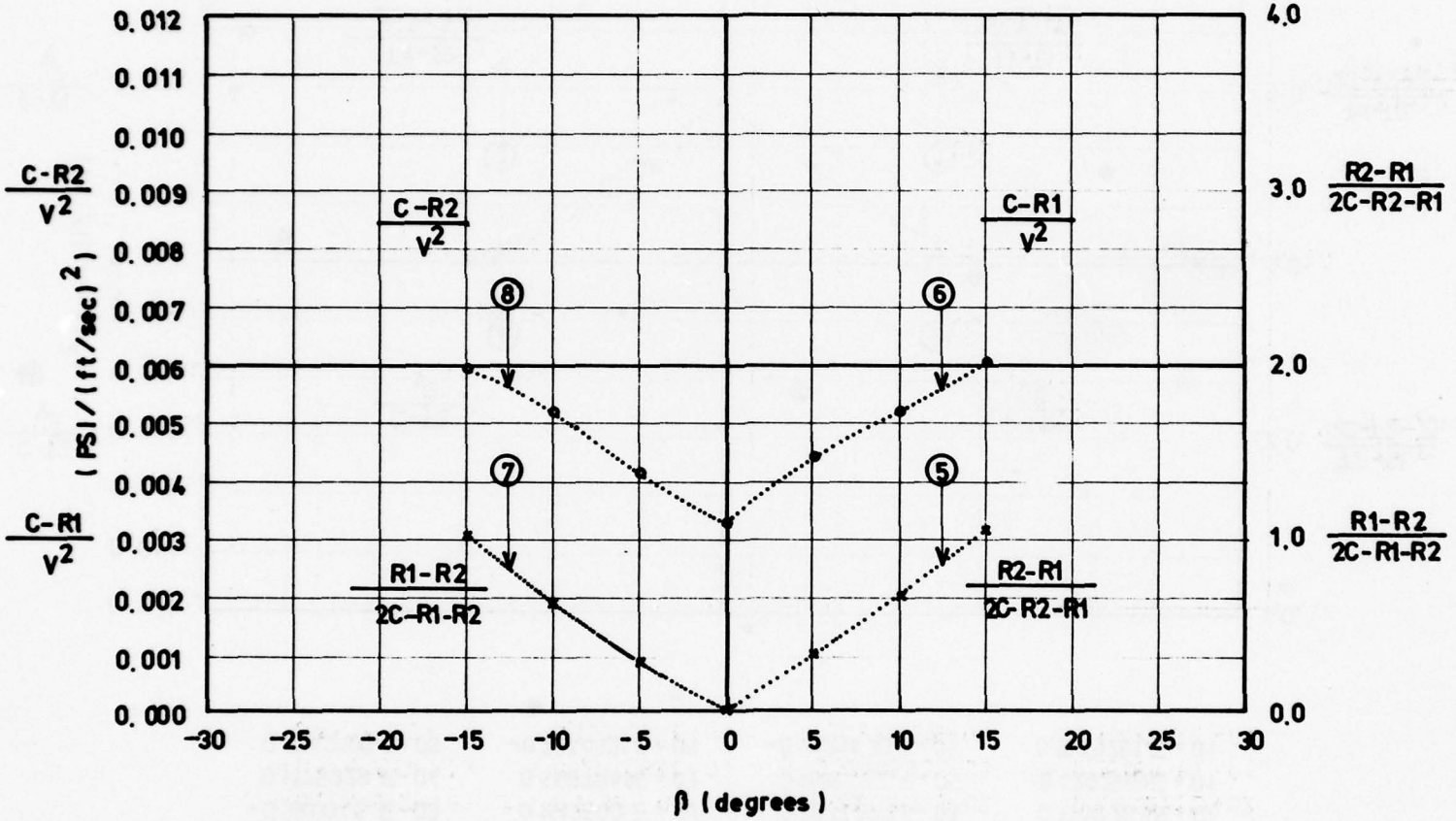
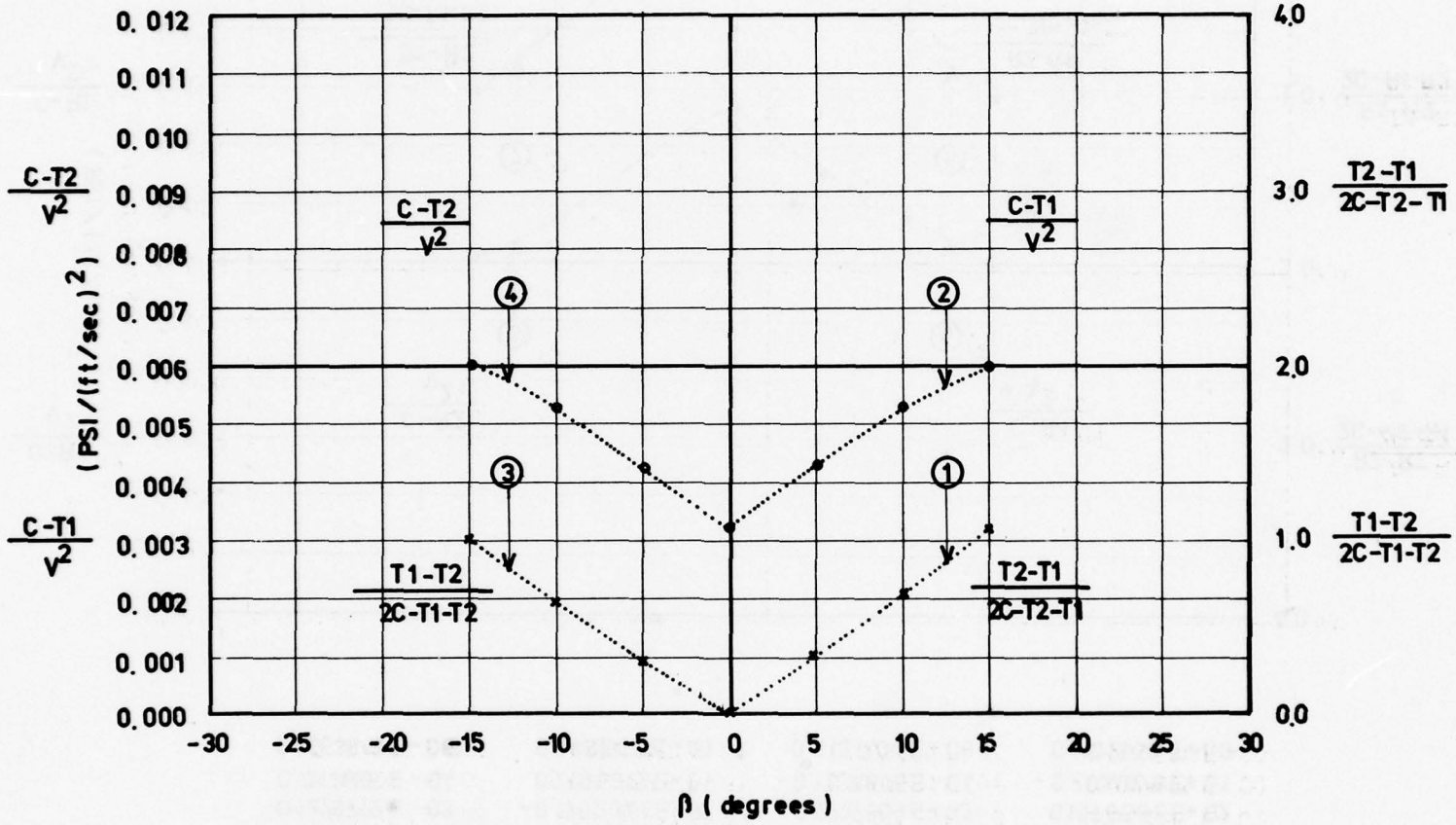


Figure 108-Post Calibration of Tube 31 in Vertical-Radial Plane

④	③	②	①
0.3258985E-02	0.2706299E+00	0.3259089E-02	-0.2555237E+00
-0.1500845 E-03	-0.1812500 E+02	0.2077222 E-03	0.1710205E+02
0.1175329 E-04	0.5667969E+01	0.1888722 E-05	-0.4292969E+01
0.6242190 E-06	-0.2644531E+01	-0.2421439 E-06	0.1675781 E+01



Figue 109 -Post Calibra tion of Tube 32 in Horizontal-Tangen tial Plane

⑧ 0.3324006E-02	⑦ 0.3674164E+00	⑥ 0.3323998E-02	⑤ -0.3271179E+00
-0.1521707E-03	-0.1733984E+02	0.2061129E-03	0.1541016 E+02
0.7119030 E-05	0.1546875 E+01	0.3091991 E-06	-0.4921875 E+00
0.3976747E-06	0.1042969 E+01	-0.1376029 E-06	-0.2695313E+00

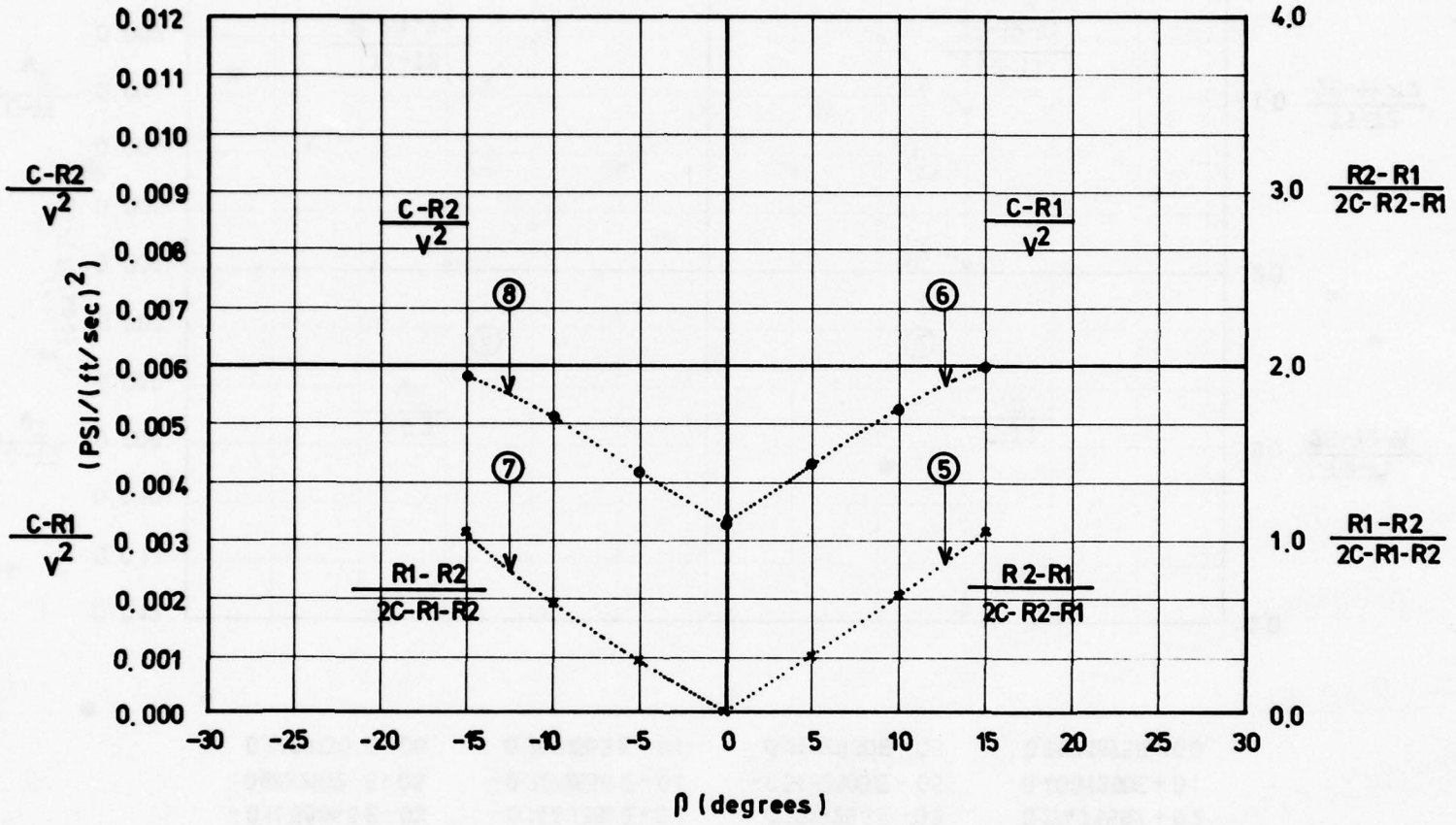


Figure 110 -Post Calibration of Tube 32 in Vertical-Radial Plane

④ 0.3268026 E-02	③ 0.1589355 E+00	② 0.3268030E-02	①-0.1921234 E+00
-0.1859665 E-03	-0.1443359 E+02	0.2313256 E-03	0.1747559E+02
0.6832182 E-05	-0.2472656 E+01	-0.5450100 E-05	-0.4031250E+01
0.4880130 E-06	0.2601563 E+01	0.1112930E-06	0.8671875E+00

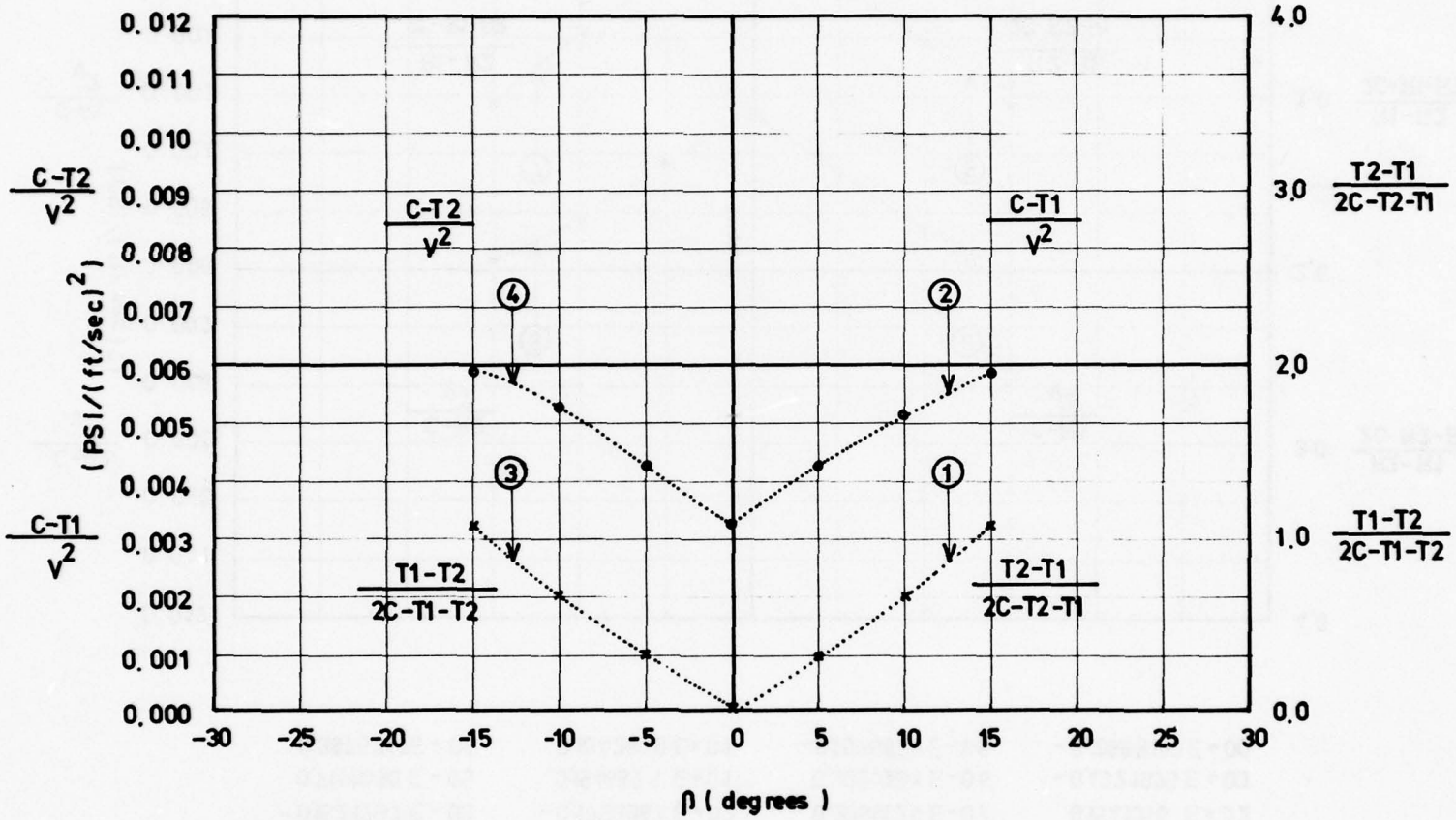


Figure 111 -Post Calibration of Tube 33 in Horizontal-Tangential Plane

⑧ 0.3288992E-02	⑦ 0.4235840E+00	⑥ 0.3289048E-02	⑤ -0.3498383E+00
-0.1619458 E-03	-01992969 E+02	01754165 E-03	01634766 E+02
0.6463379E-05	09542969E+01	0.6701797E-05	-0.2660156 E+01
0.3930181 E-06	-0.4382812E+01	-0.4097819E-06	0.1121094 E+01

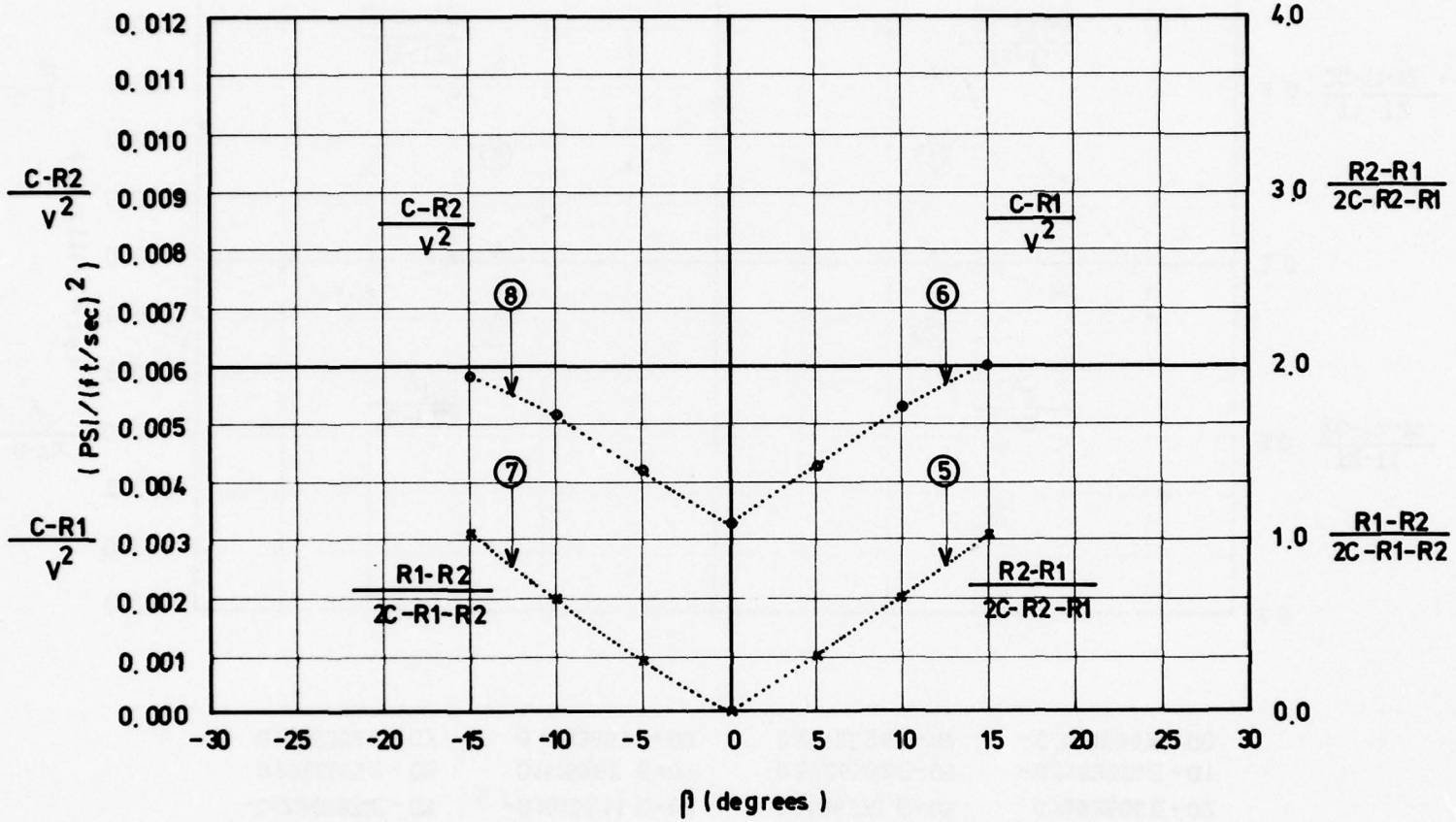


Figure 112 -Post Calibration of Tube 33 in Vertical-Radial Plane

④	③	②	①
0.3217161 E - 02	0.7128906 E - 01	0.3214598 E - 02	-0.1761169 E + 00
-0.2340674 E - 03	-0.1616211 E + 02	0.2596378 E - 03	0.1593506 E + 02
-0.2764165 E - 05	0.1115967 E + 01	-0.5226582 E - 05	-0.1163574 E + 01
0.3068999 E - 07	0.4213867 E + 00	0.2613524 E - 07	-0.3796387 E + 00

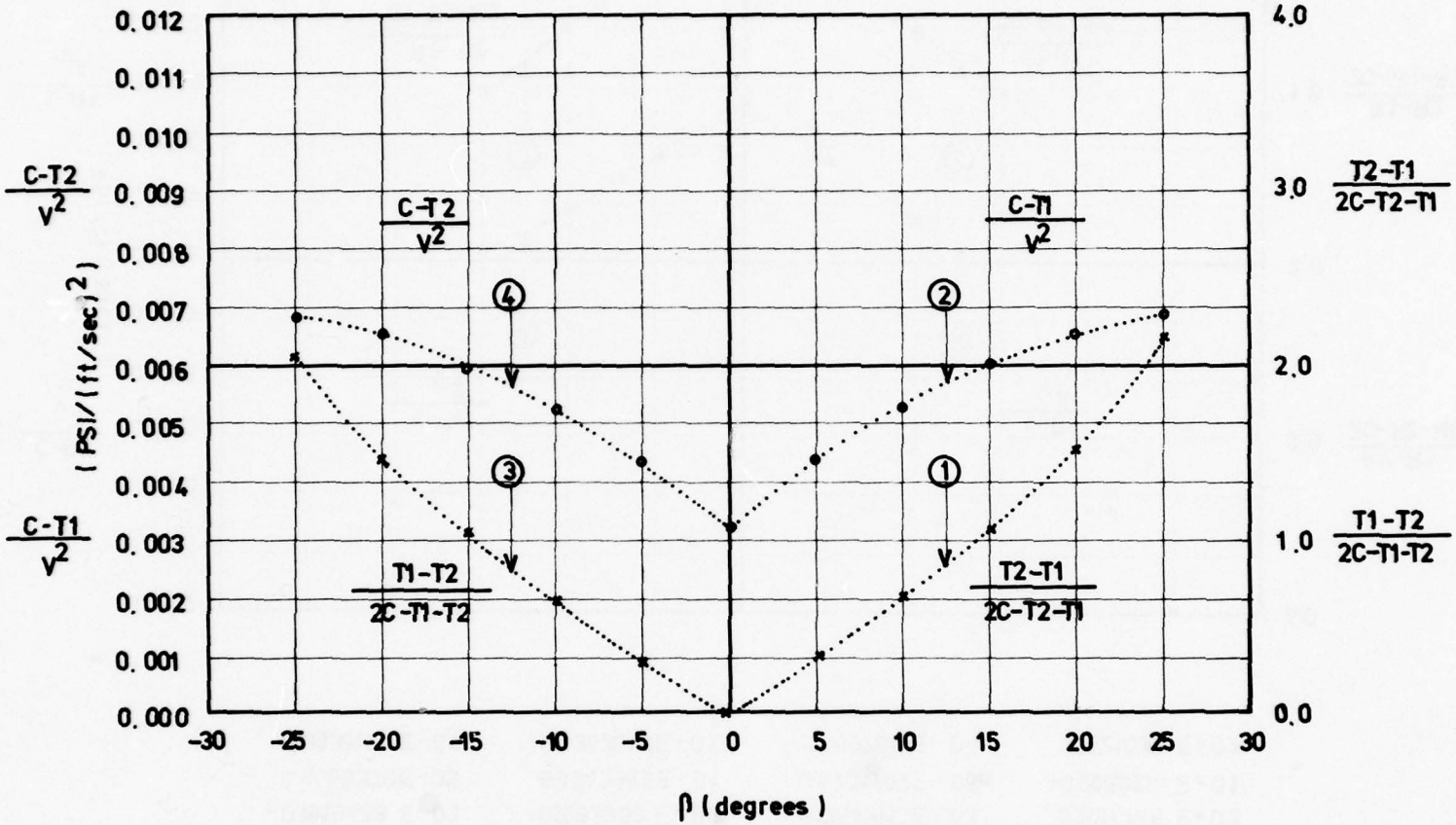


Figure 113 -Post Calibration of Tube 34 in Horizontal-Tangential Plane

⑧	⑦	⑥	⑤
0.3299415 E-02	0.4531250E + 00	3309667 E- 02	-0.3142090E + 00
-0.1611710 E-03	-0.1969141E + 02	0.1955032E - 03	0.1281641 E + 02
0.6258488 E-05	0.6964844E + 01	0.5125999E - 05	0.7609375 E + 01
0.4731119 E-06	-0.3175781 E + 01	-0.5885959E - 06	-0.7492188 E + 01
0.7348717 E-08	0.7773438E + 00	0.1232547 E - 07	0.1785156 E + 01

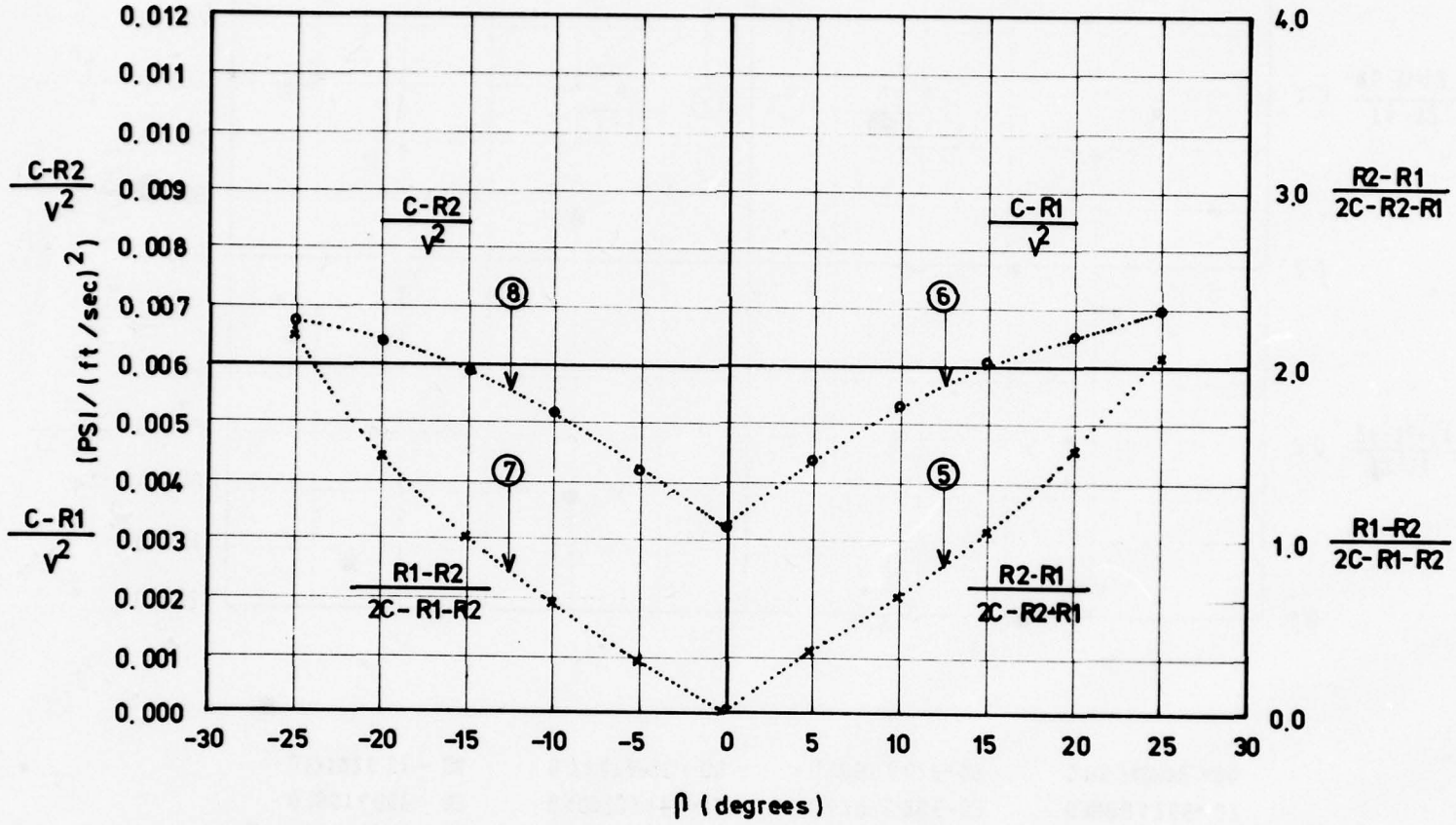


Figure 114 - Post Calibration of Tube 34 in Vertical - Radial Plane

④	③	②	①
0.1511987 E - 02	0.1273193 E + 00	0.1511972 E-02	-0.1292114 E +00
-0.1651496E - 03	-0.1071021 E + 02	0.1707599 E-03	0.1086426E +02
-0.1715263 E - 05	0.7147369E + 00	-0.2055662 E-05	-0.8524017E +00

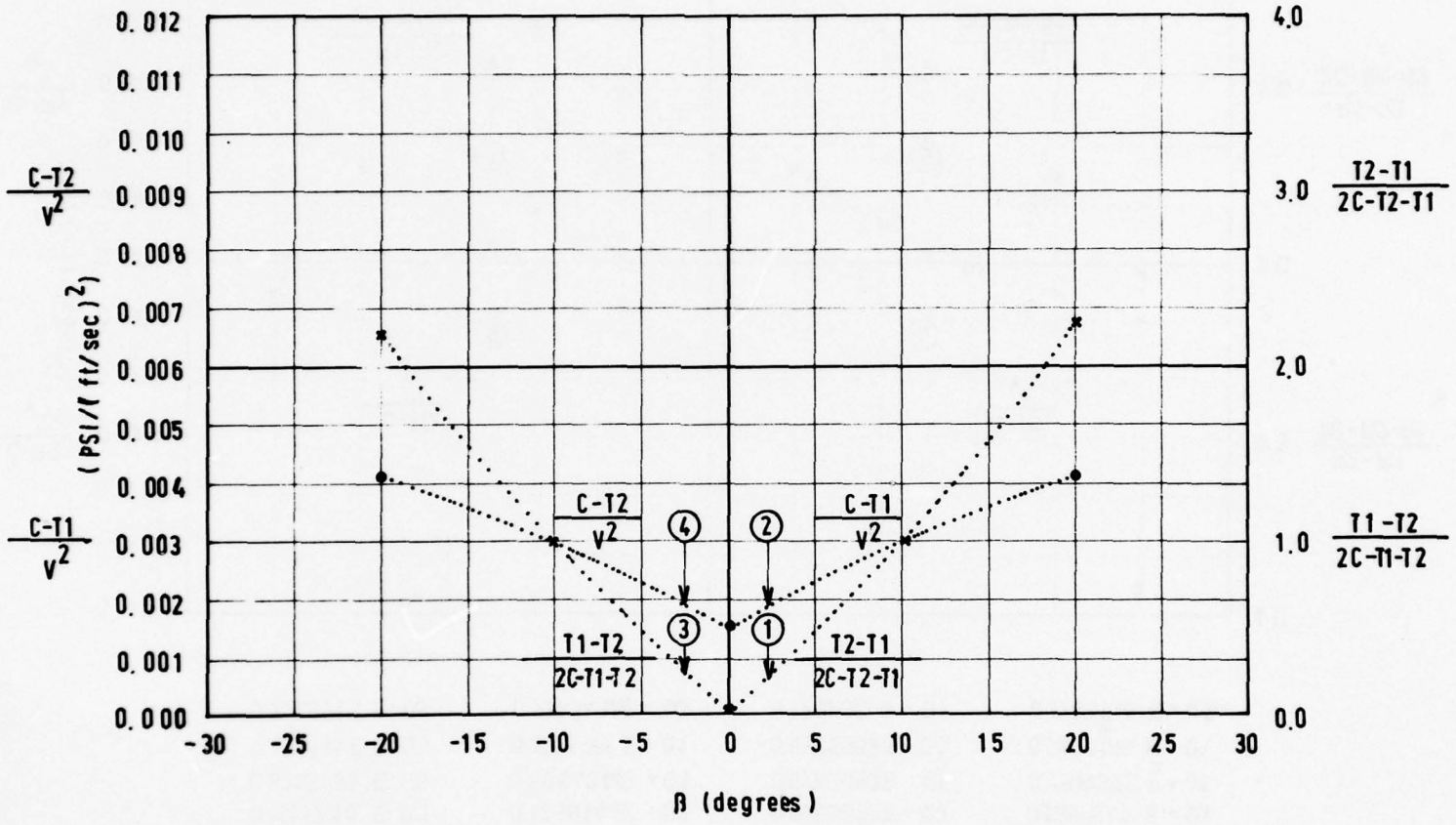


Figure 115 -Pre Calibration of Tube 36 in Horizontal-Tangential Plane holes 7,6,8,3,11

⑧ 0.1534980E - 02	⑦ 0.3217773E+00	⑥ 0.1534980E - 02	⑤ - 0.3016968E + 00
- 0.1529045E - 03	- 0.1 11 4136E + 02	0.1661070 E - 03	0.1044189E + 02
- 0.1110602E - 05	0.755 4169 E + 00	- 0.1700595E - 05	- 0.5858154E + 00

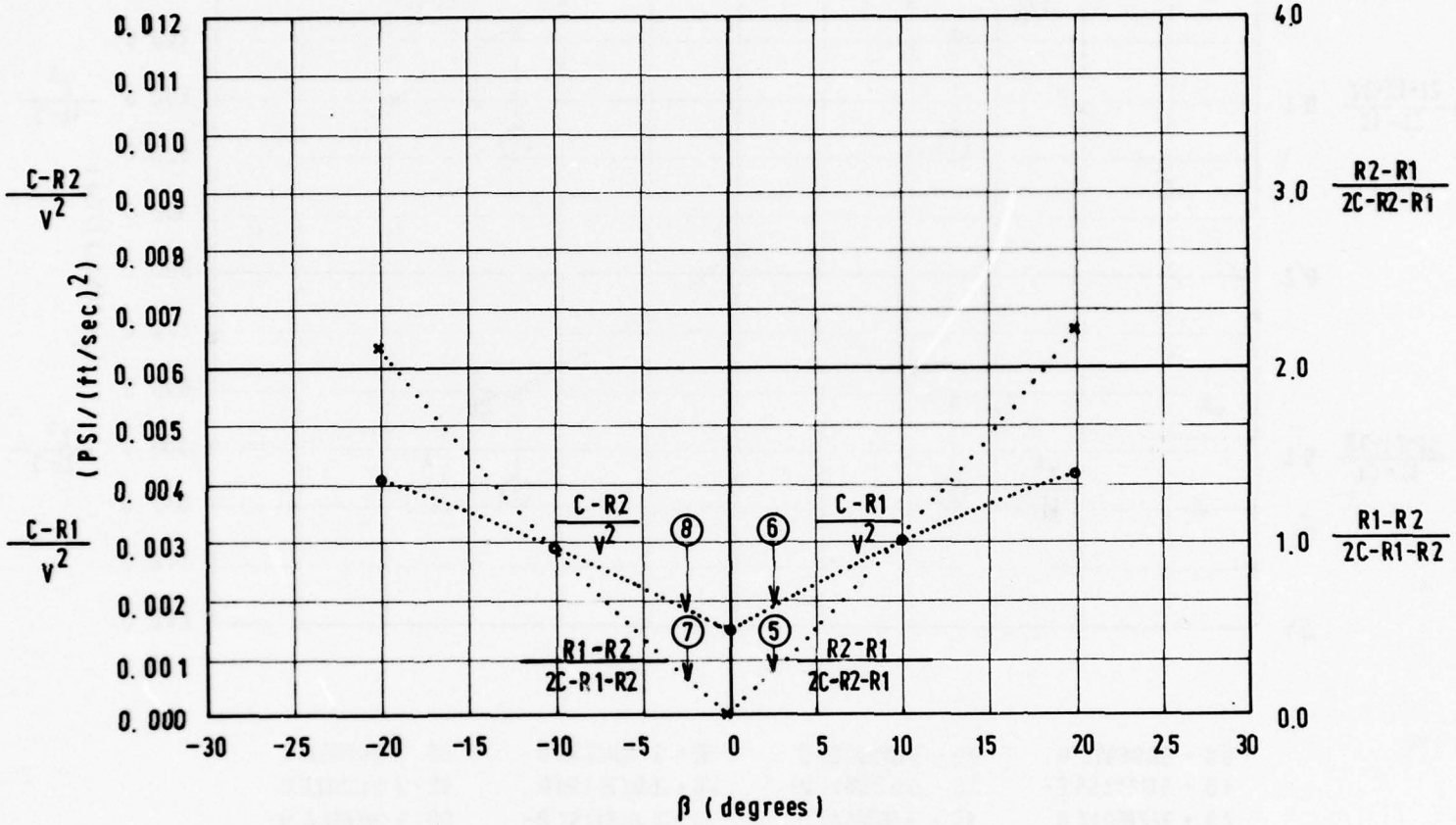


Figure 116 - Pre Calibration of Tube 36 in Vertical - Radial Plane holes 7.6.8 .3 .11

④ 0.5608786E-02	③ 0.1367188E+00	② 0.5608838E-02	① -0.1320801E+00
-0.2339482E-03	-0.2574219E+02	0.2759099E-03	0.2469922E+02
-0.3714114E-05	0.6671875E+01	-0.7495284E-05	-0.5574219E+01
0.1526496E 07	-0.5537109E+00	0.6025948E-07	0.2453613E+00

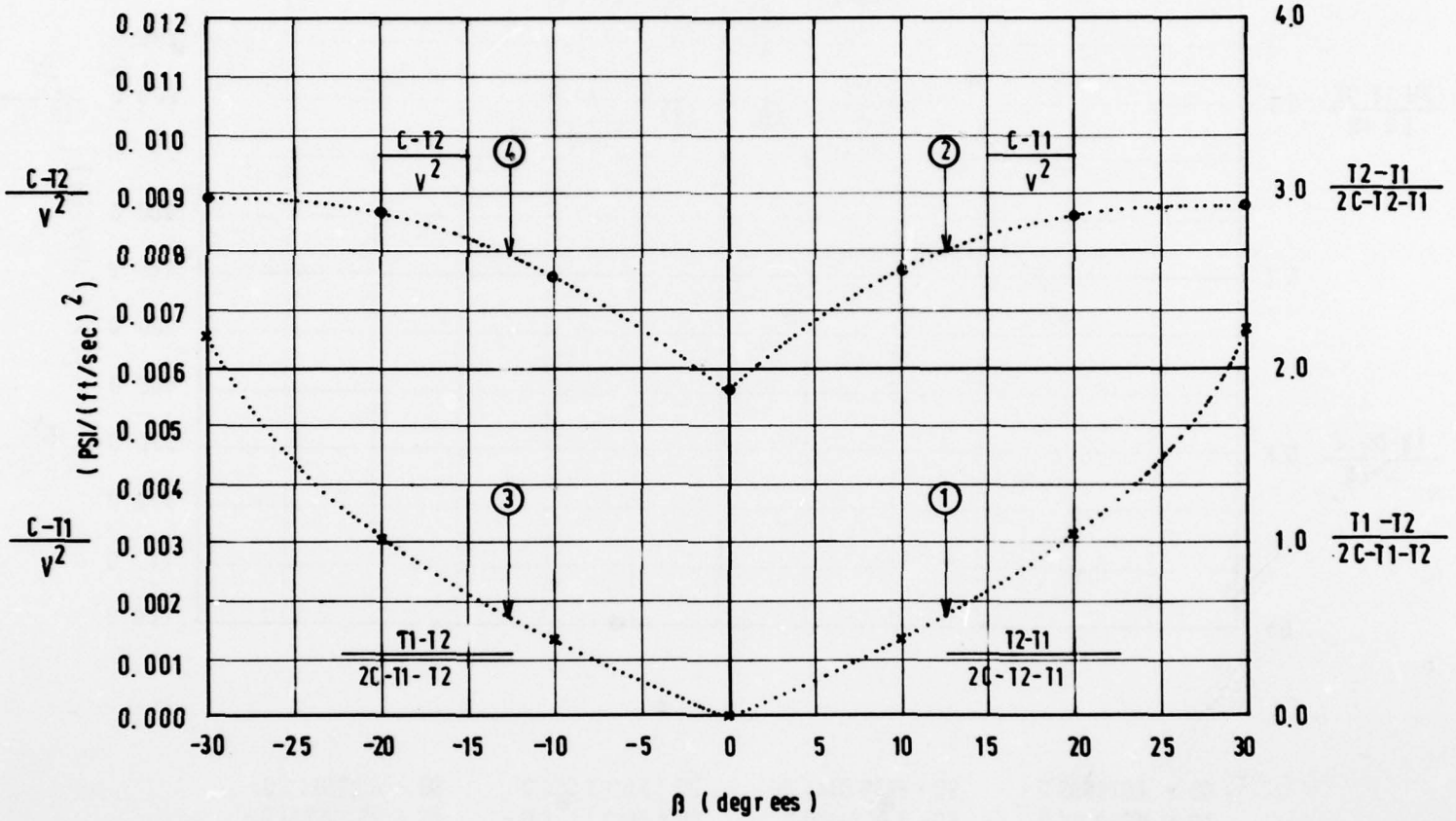


Figure 117 -Pre Calibration of Tube 36 in Horizontal-Tangential Plane holes 7.5.9.1.13

⑧	⑦	⑥	⑤
0.5633846 E - 02	0.3181152 E + 00	0.5633853 E - 02	- 0.2980957 E + 00
- 0.2341866 E - 03	- 0.2673047 E + 02	0.2545118 E - 03	0.2491406 E + 02
- 0.4041940 E - 05	0.7371094 E + 01	- 0.5293638 E - 05	- 0.5503906 E + 01
0.1289300 E - 07	- 0.6687012 E + 00	0.1607987 E - 07	0.2094727 E + 00

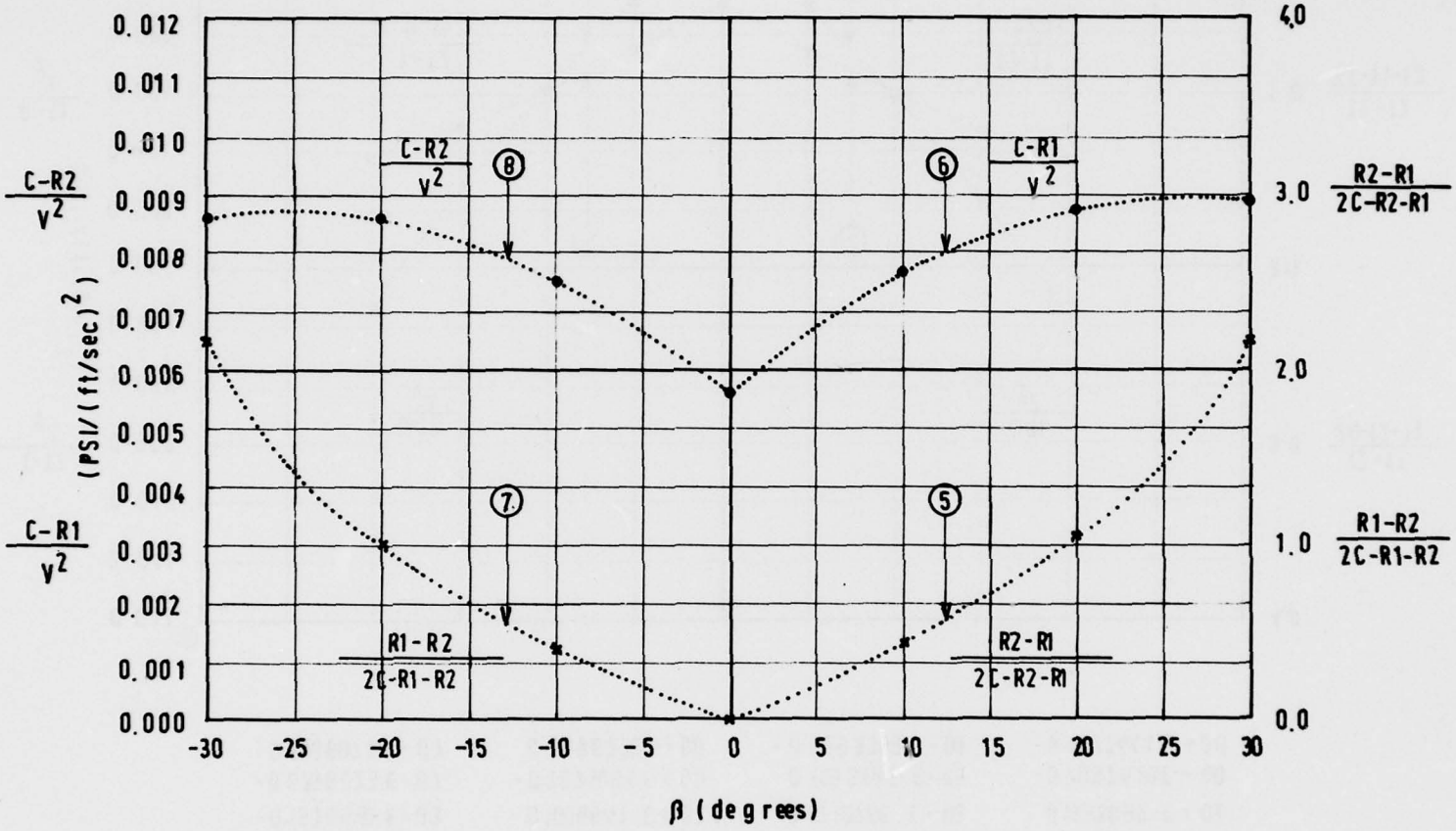


Figure 118 -Pre Calibration of Tube 36 in Vertical-Radial Plane
holes 7.5, 9, 1, 13

④	③	②	①
0.1497749 E-02	0.1029205 E+00	0.1494009 E-02	-0.1665497E+00
-0.1536570 E-03	-0.1006641 E+02	0.1710765 E-03	0.1025098 E+02
-0.6705523 E-07	-0.2871094 E+00	-0.1855195 E-05	-0.2082520E+00
0.5908078 E-07	0.3386230E+00	-0.5995389 E-08	-0.1877441 E+00

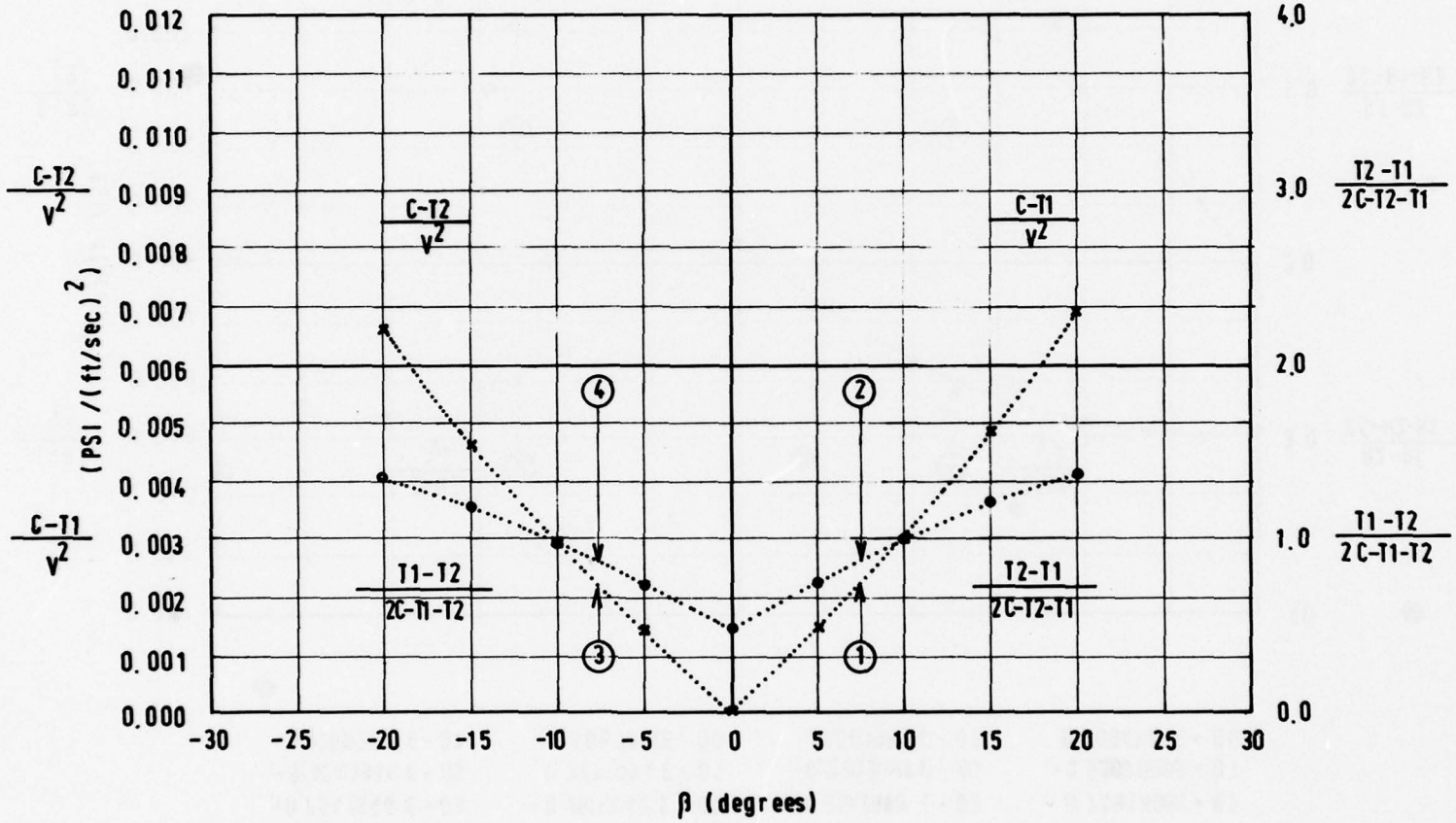


Figure 119-Pre Calibration of Tube 37 in Horizontal-Tangential Plane holes 7,6,8,3,11

⑧ 0.1576416 E - 02	⑦ 0.660888 7E + 00	⑥ 0.1576845E - 02	⑤ -0.5043945 E + 00
- 0.1090765 E - 03	-0.1382178E + 02	0.1613908 E - 03	0.1021802 E + 02
0.3453344E - 05	0.3498535E + 01	-0.1423061E - 05	- 0.1857910 E + 00
-0.1353765 E - 06	-0.7165527 E + 00	-0.5995389 E - 08	- 0.1520996E + 00

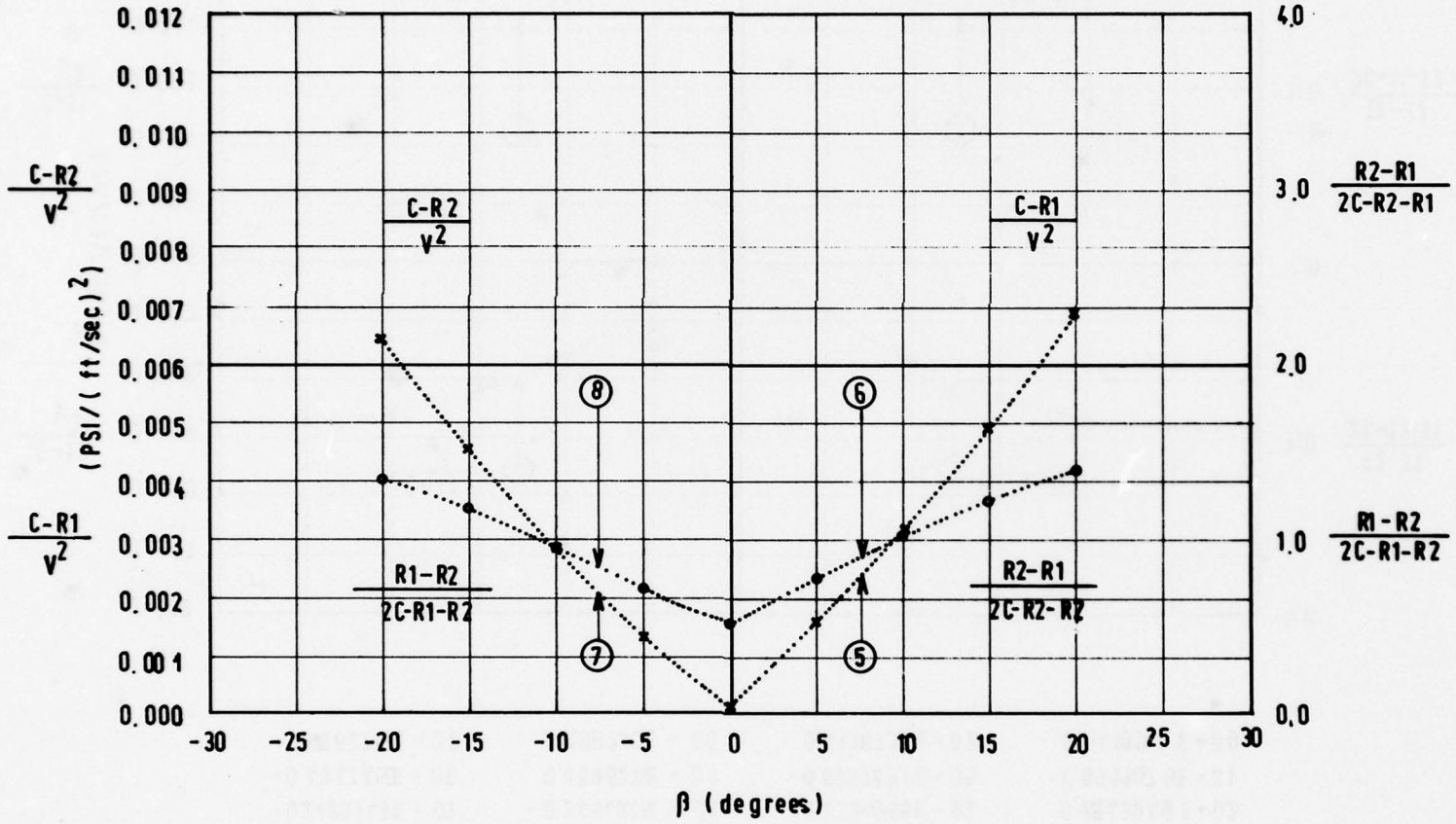


Figure 120 - Pre Calibration of Tube 37 in Vertical-Radial Plane
holes 7,6,8,3,11

④	③	②	①
0.5576968 E - 02	0.6062012E + 00	0.5569398 E - 02	-0.2194824 E+00
-0.2480149E - 03	-0.2454321E + 02	0.2734065E - 03	0.2543848 E+02
-0.4943460E - 05	0.4595215E + 01	-0.6757677E - 05	-0.6551025E+01
-0.4962203E - 08	0.1198730E + 00	0.4116737E - 07	0.5410156 E+00

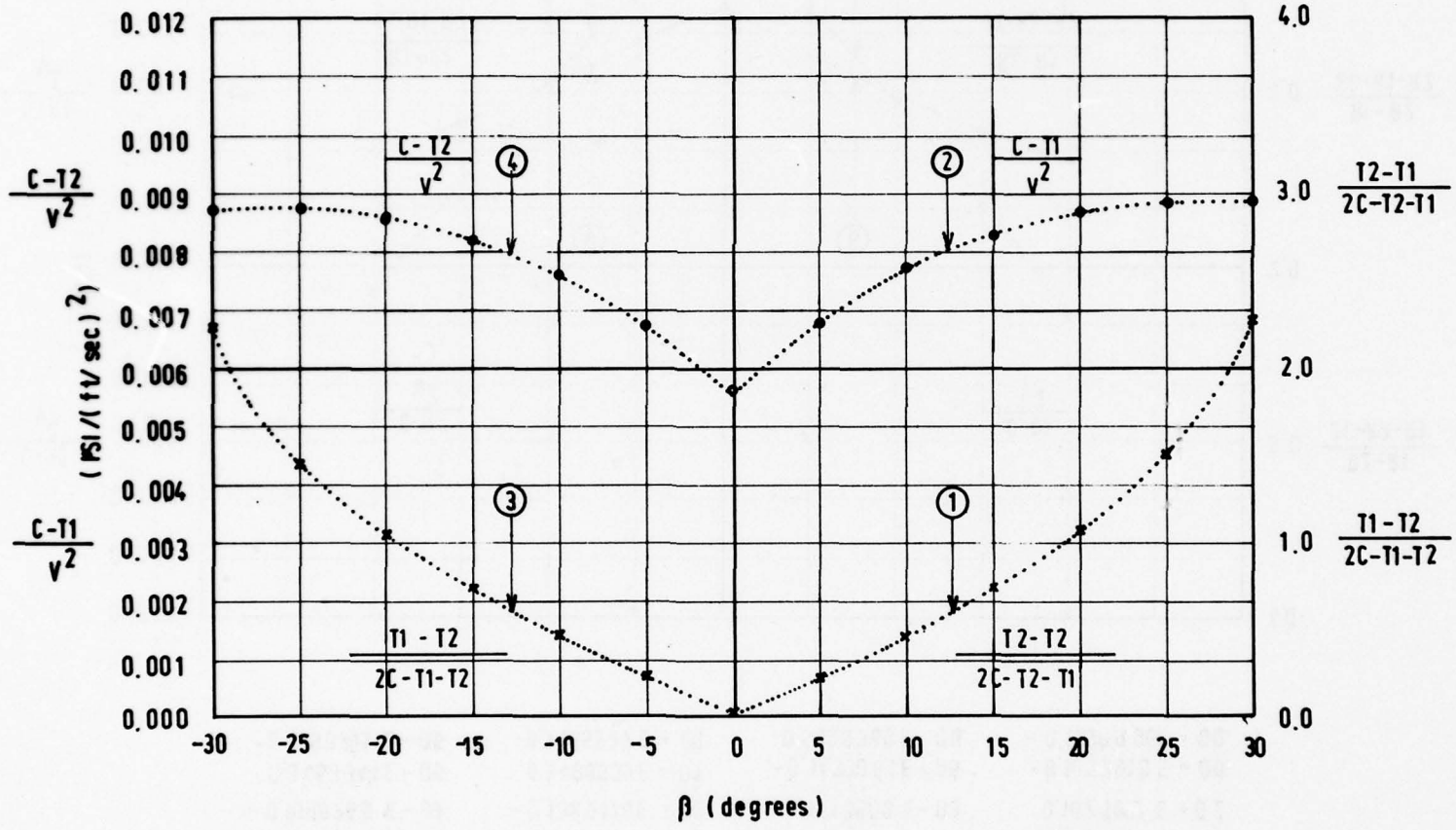


Figure 121 -Pre Calibration of Tube 37 in Horizontal-Tangential Plane holes 7.5.9.1.13

⑧ 0.5679488 E-02	⑦ 0.4826660E+00	⑥ 0.5708754E-02	⑤ -0.6643066E+00
-0.2136827E-03	-0.2868701E+02	0.2536774E-03	0.2582520E+02
-0.3326684 E-05	0.9718750E+01	-0.5241483 E-05	-0.6802490E+01
0.1993612 E-07	-0.1364258E+01	0.8483767 E-08	0.6083984E+00

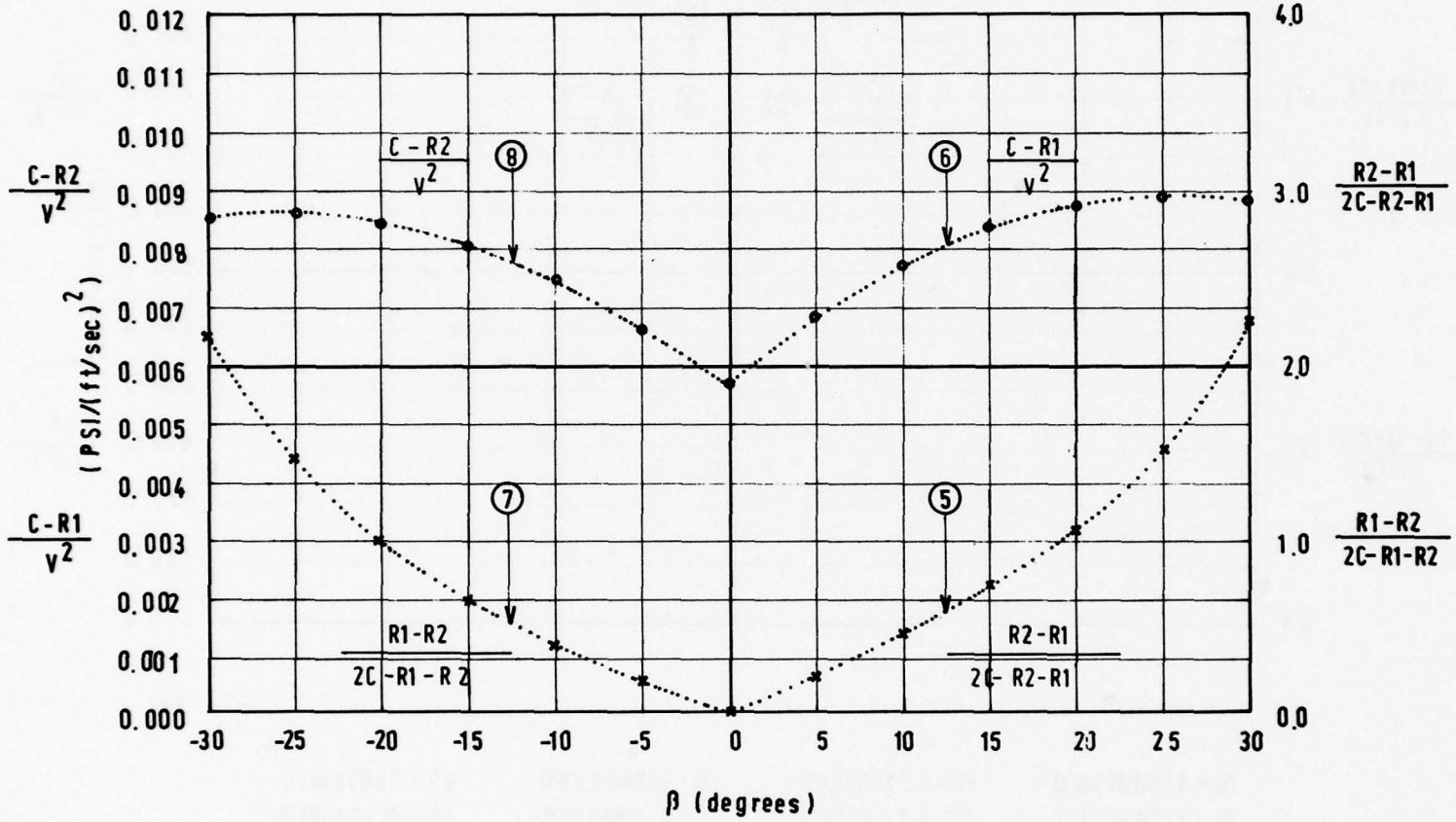


Figure 122 -Pre Calibration of Tube 37 in Vertical-Radial Plane holes 7,5,9,1,13

④ 0.1492981E - 02	③ 0.2645874E-01	② 0.1492981E-02	① - 0.2711487E - 01
-0.1667552E - 03	-0.1068997E+02	0.1617074E-03	0.1098804E + 02
-0.1915498E - 05	0.8549957E+00	-0.1540640E - 05	- 0.8510895E + 00

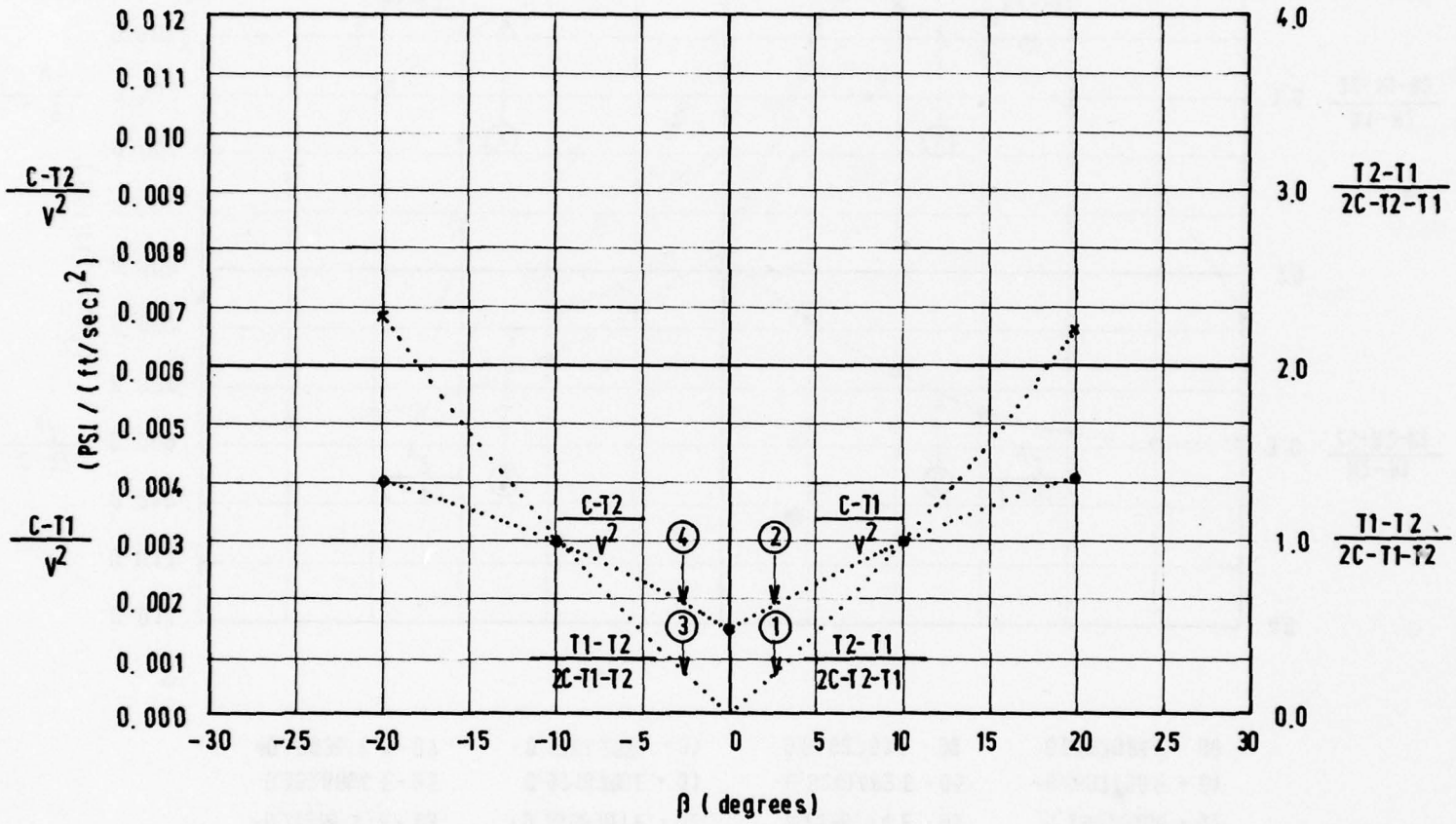


Figure 123 -Pre Calibration of Tube 38 in Horizontal-Tangential Plane holes 7,6,8,3,11

⑧	⑦	⑥	⑤
0.1545988E-02	0.4062500E+00	0.1545984E-02	-0.3699493E+00
-0.1505055E-03	-0.1161230E+02	0.1636520E-03	0.1056958E+02
-0.1220498E-05	0.9341583E+00	-0.1715263E-05	-0.7212067E+00

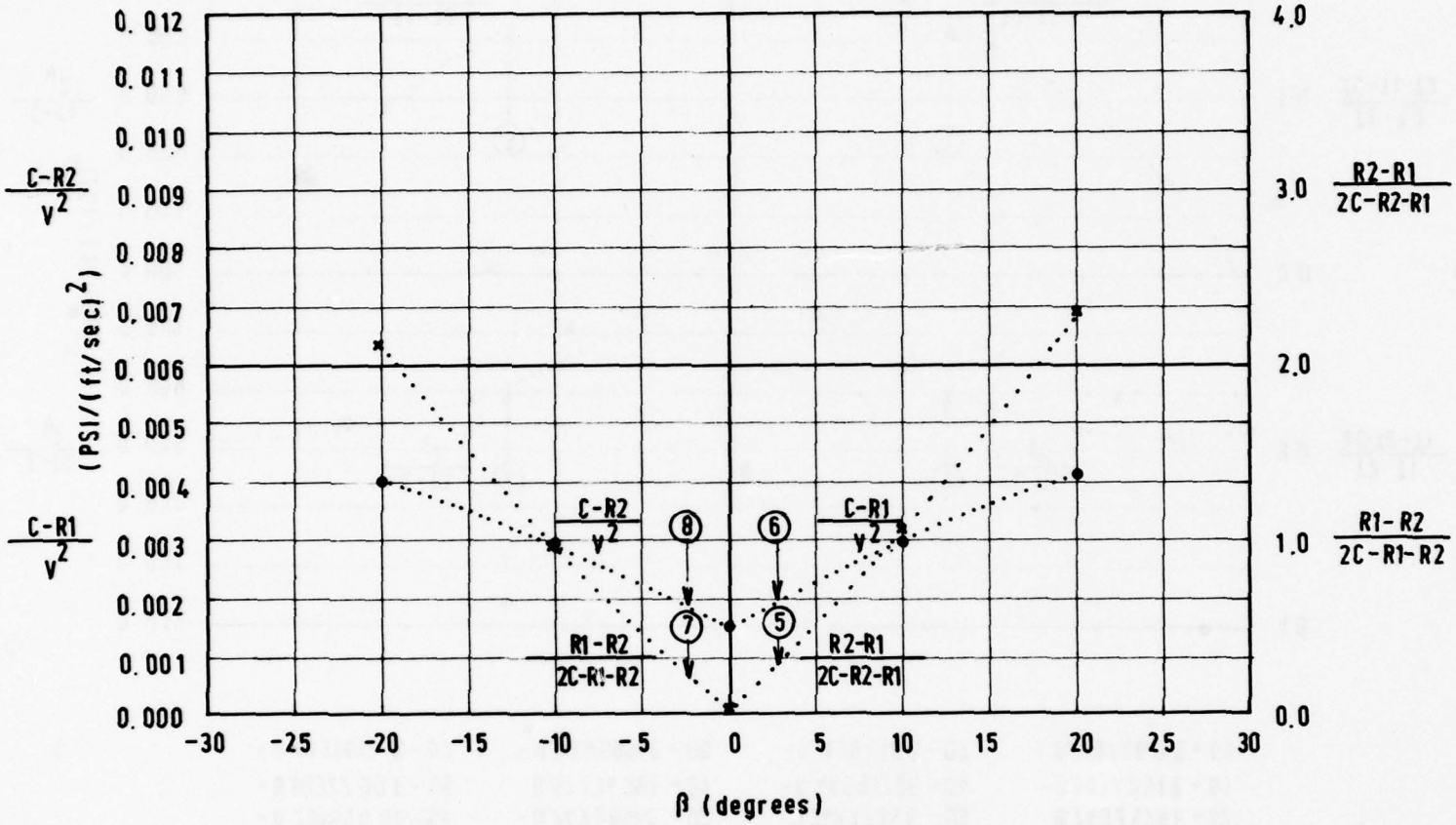


Figure 124 -Pre Calibration of Tube 38 in Vertical-Radial Plane
holes 7,6,8,3,11

④ 0.5574860E-02	③ 0.2514648E-01	② 0.5574800E-02	① -0.2490234E-01
-0.2546906E-03	-0.2472656E+02	0.2477765E-03	0.2492578E+02
-0.6072230E-05	0.5773438E+01	-0.4459172E-05	-0.5613281E+01
-0.4039612 E-07	-0.3395996E+00	-0.1139415E-07	0.2197266E+00

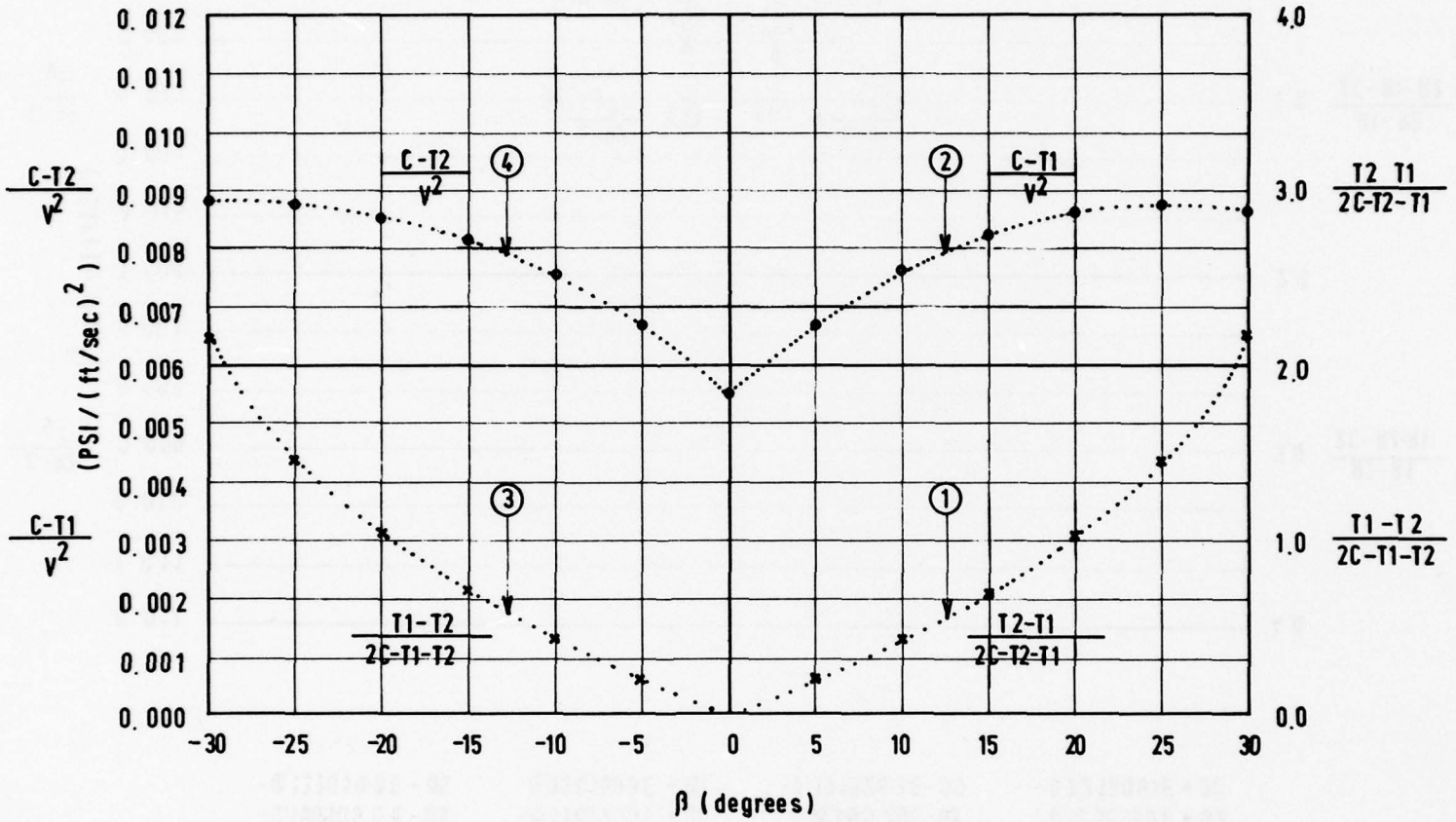


Figure 125 -Pre Calibration of Tube 38 in Horizontal-Tangential Plane holes 7,5,9,1,13

⑧ 0.5622845E-02	⑦ 0.4436035E+00	⑥ 0.5622849E-02	⑤ -0.4079590E+00
-0.2231598E-03	-0.2721094E+02	0.2538562E-03	0.2501562E+02
-0.3170222E-05	0.7742187E+01	-0.4857779E-05	-0.5753906E+01
0.3744208E-07	-0.7509766E+00	-0.4234607E-08	0.2668652E+00

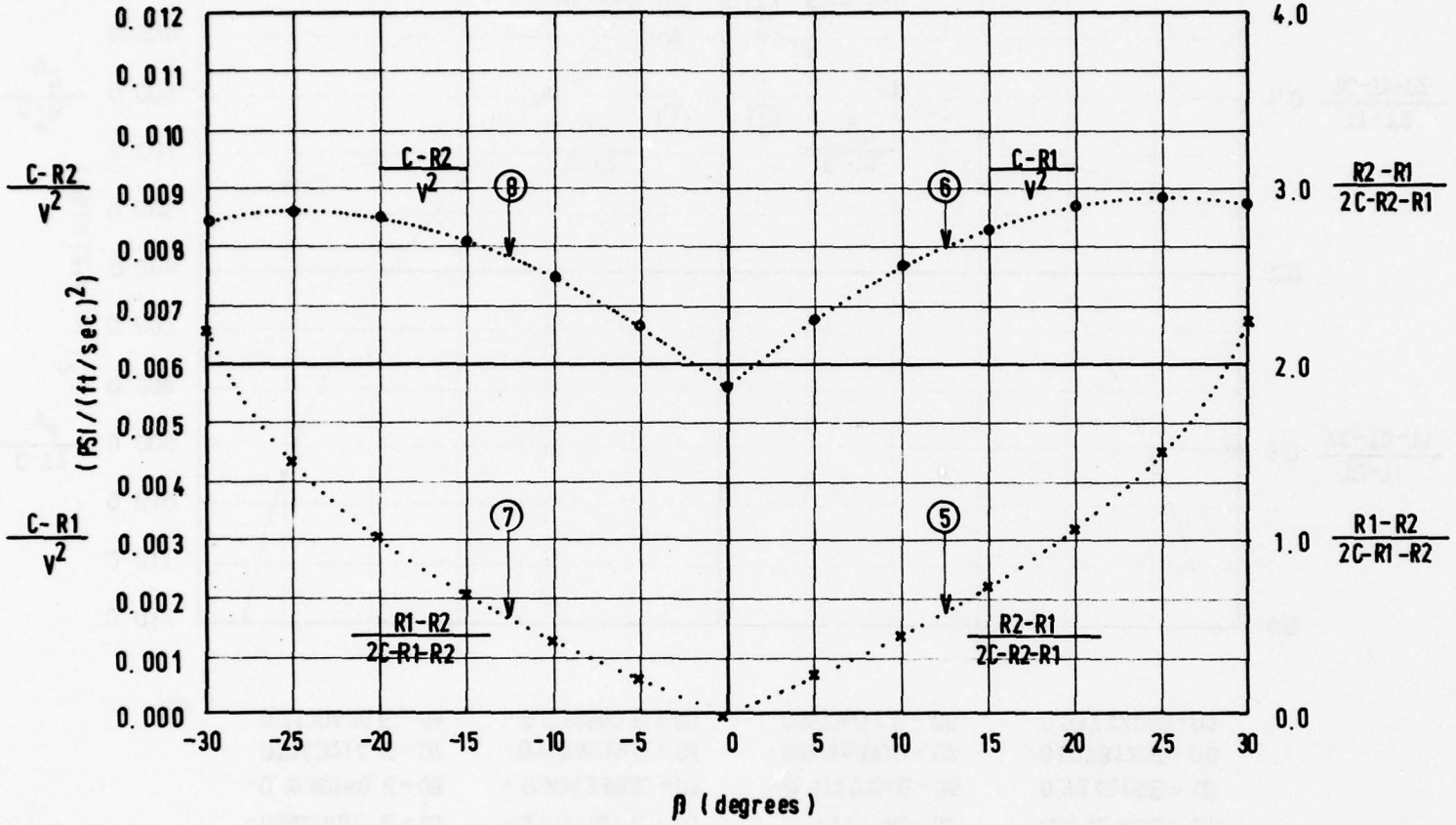


Figure 126-Pre Calibration of Tube 38 in Vertical-Radial Plane
holes 7.5.9.1.13

④	③	②	①
0.1428902 E - 02	0.5444336 E - 01	0.1421571 E - 02	-0.9545898 E - 01
-0.1803637 E - 03	-0.9117187 E + 01	0.1732111 E - 03	0.1042188 E + 02
-0.1836568 E - 05	-0.2042969 E +01	-0.5178154 E - 06	0.3242188 E + 00
0.3143214 E - 07	0.1199219 E + 01	-0.9196810 E - 07	-0.5078125 E + 00
0.7130438 E - 09	-0.1359863 E + 00	0.1571607 E - 08	0.5322266 E - 01

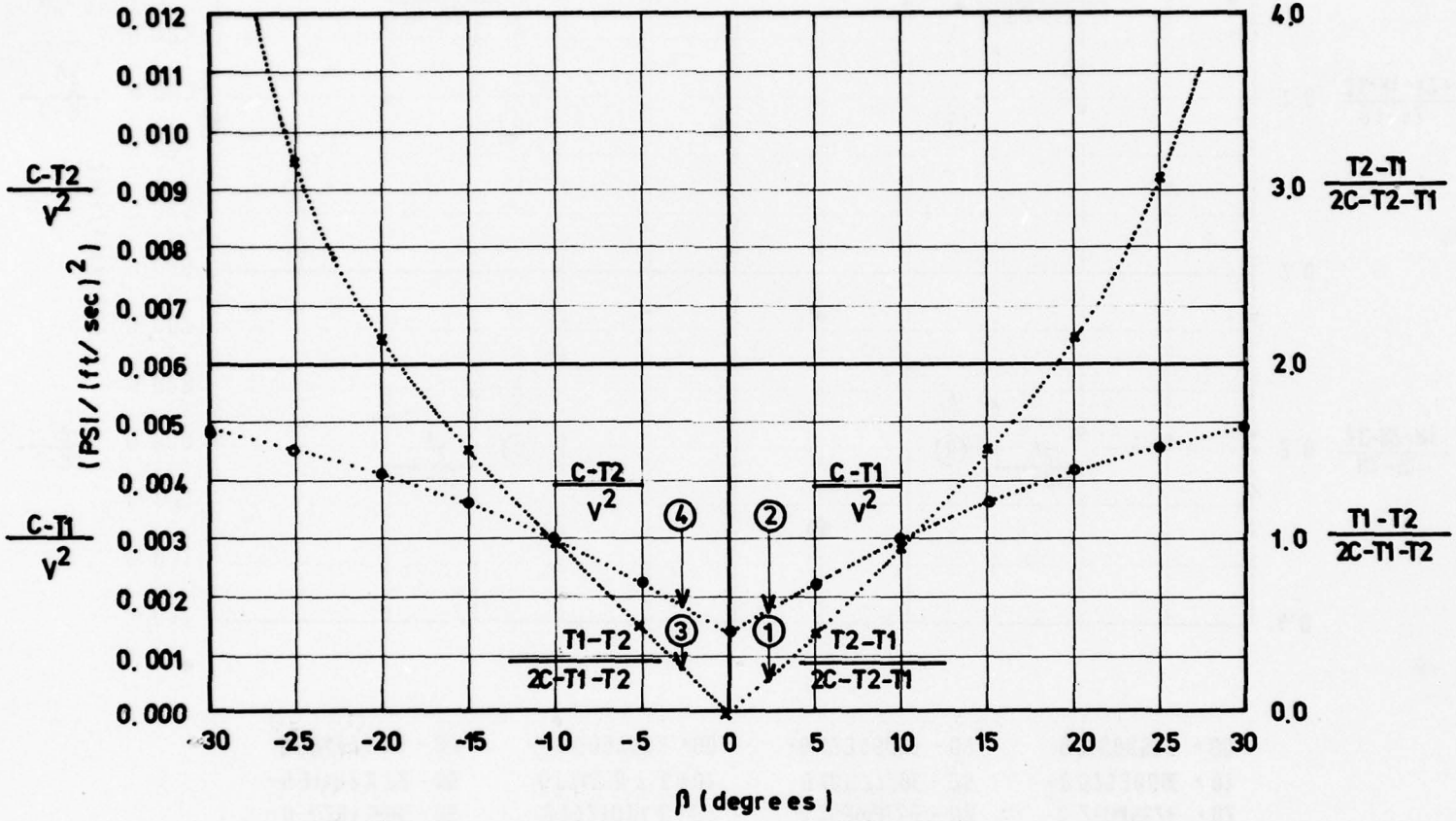


Figure 127 -Post Calibration of Tube 37 in Horizontal-Tangential Plane holes 7.6.8.3.11

⑧ 0.1493912 E-02	⑦ 0.1181396E+01	⑥ 0.1479585E-02	⑤ -0.1120361E+01
-0.1448318 E-03	-0.1361230E+02	0.1756065E-03	0.1177954E+02
0.4509930 E-06	0.1870605 E+01	-0.2254033E-05	-0.1402832E+01
0.5752372 E-07	-0.8503723E-01	-0.2022716E-08	0.5187988E-01

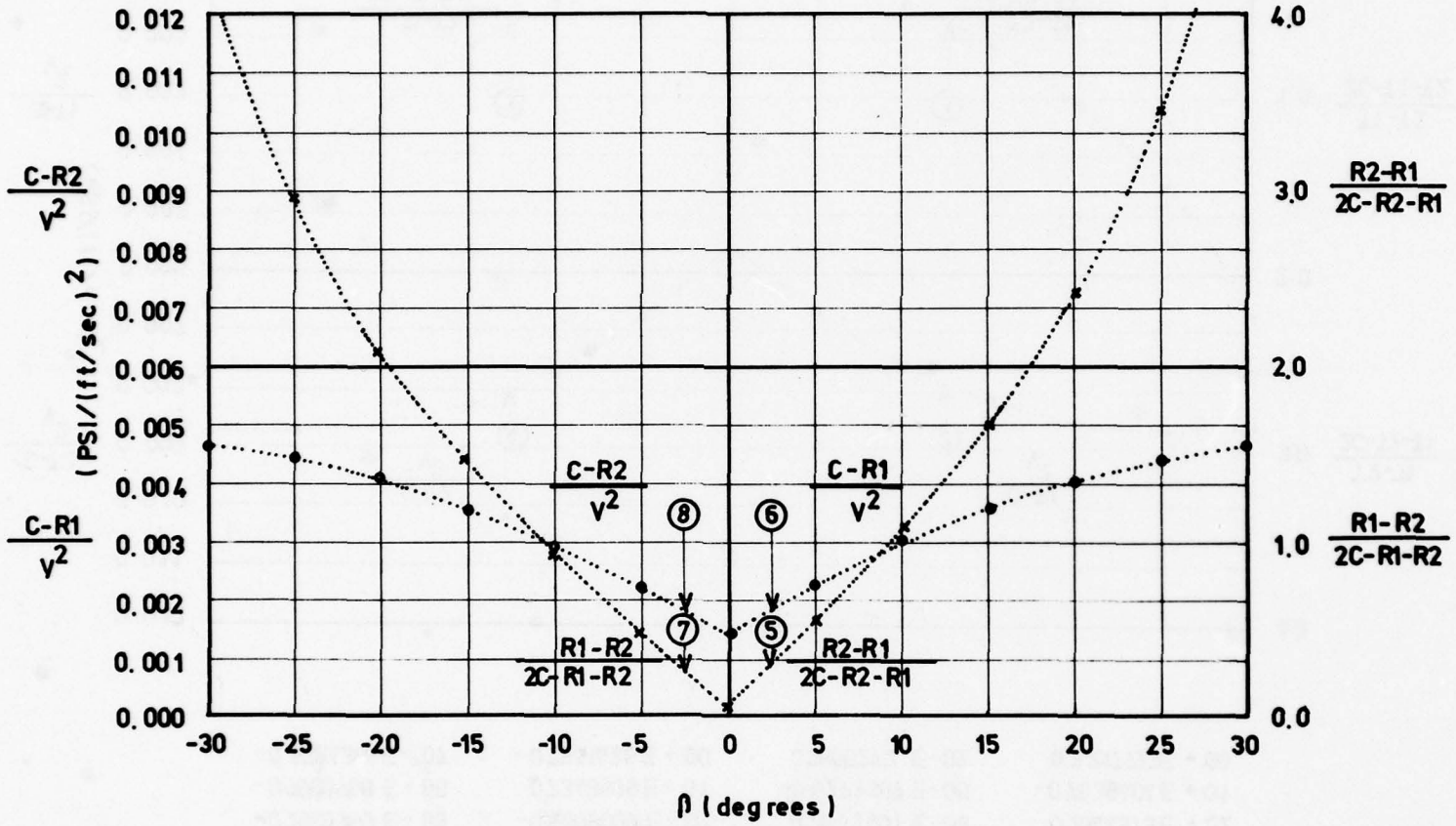


Figure 128 - Post Calibration of Tube 37 in Vertical-Radial Plane
holes 7.6.8.3.11

④	③	②	①
0.5484879E-02	0.3129883E+00	0.5483568E-02	-0.2504883E+00
-0.2900362E-03	-0.2609009E+02	0.2683401E-03	0.2644873E+02
-0.7800758E-05	0.7349609E+01	-0.6273389E-05	-0.7639404E+01
-0.5784386E-07	-0.7961426E+00	0.2865272E-07	0.8217773E+00

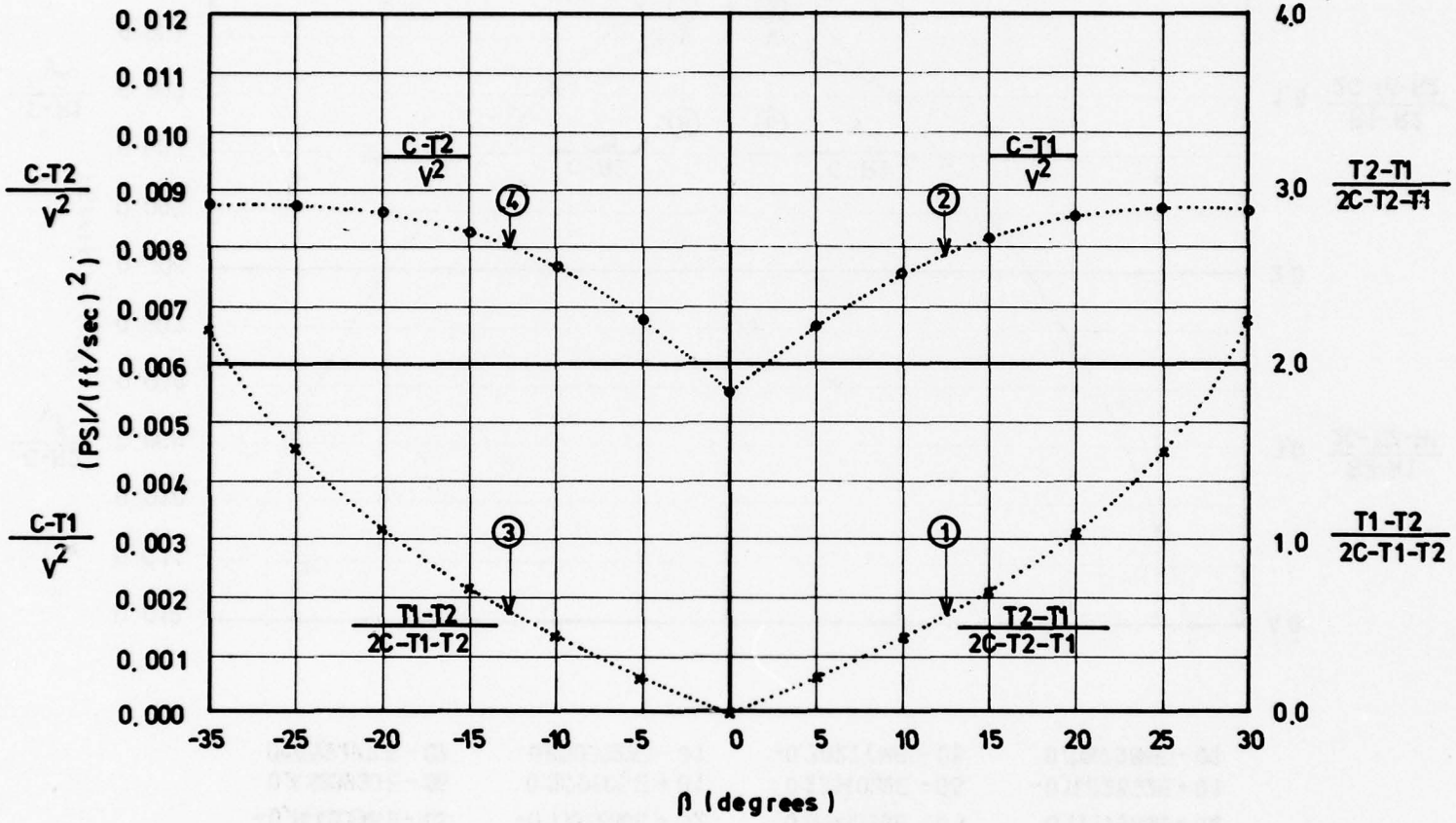


Figure 129 -Post Calibration of Tube 37 in Horizontal-Tangential Plane holes 7.5.9.1.13

⑧	⑦	⑥	⑤
0.5589008E - 02	0.4711914E + 00	0.5581021E - 02	-0.5759277E + 00
-0.2282858E - 03	-0.2783398E + 02	0.2692938E - 03	0.2553833E + 02
-0.2544373E - 05	0.8450439E + 01	-0.6280839E - 05	-0.6942139E + 01
0.5900802E - 07	-0.9533691E + 00	0.2510205E - 07	0.6887207E + 00

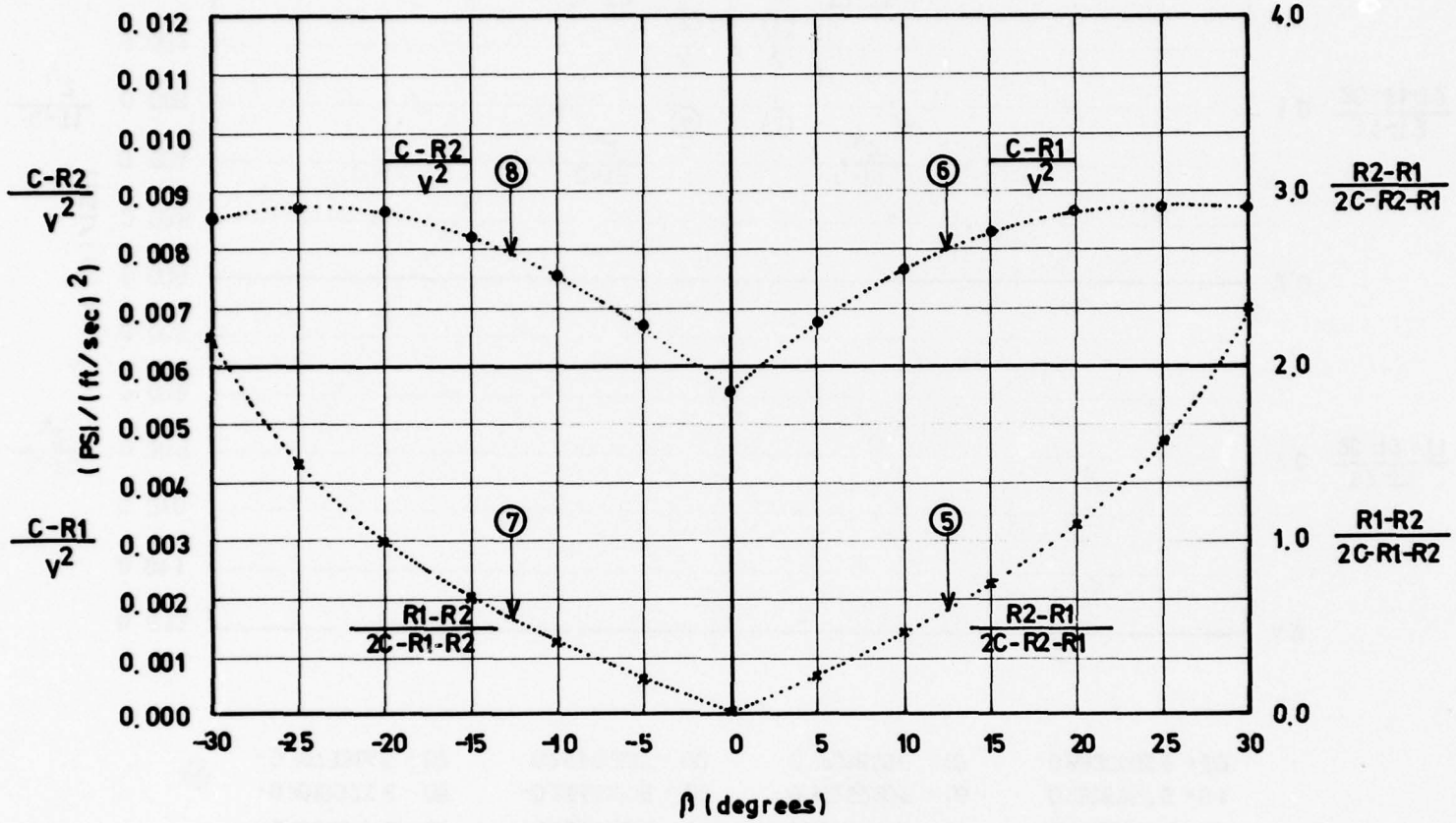


Figure 130 - Post Calibration of Tube 37 in Vertical-Radial Plane holes 7.5.9.1.13

④ 0.1535963 E - 02	③ 0.2194824 E + 00	② 0.1539994 E - 02	① -0.2893066 E + 00
-0.1954511 E - 03	-0.9966309 E + 01	0.1782514 E - 03	0.8429688 E + 01
-0.3810972 E - 05	-0.2661133 E + 00	-0.3725290 E - 06	0.2516357 E + 01
-0.3073364 E - 07	0.2939453 E + 00	-0.5801849 E - 07	-0.8337402 E + 00

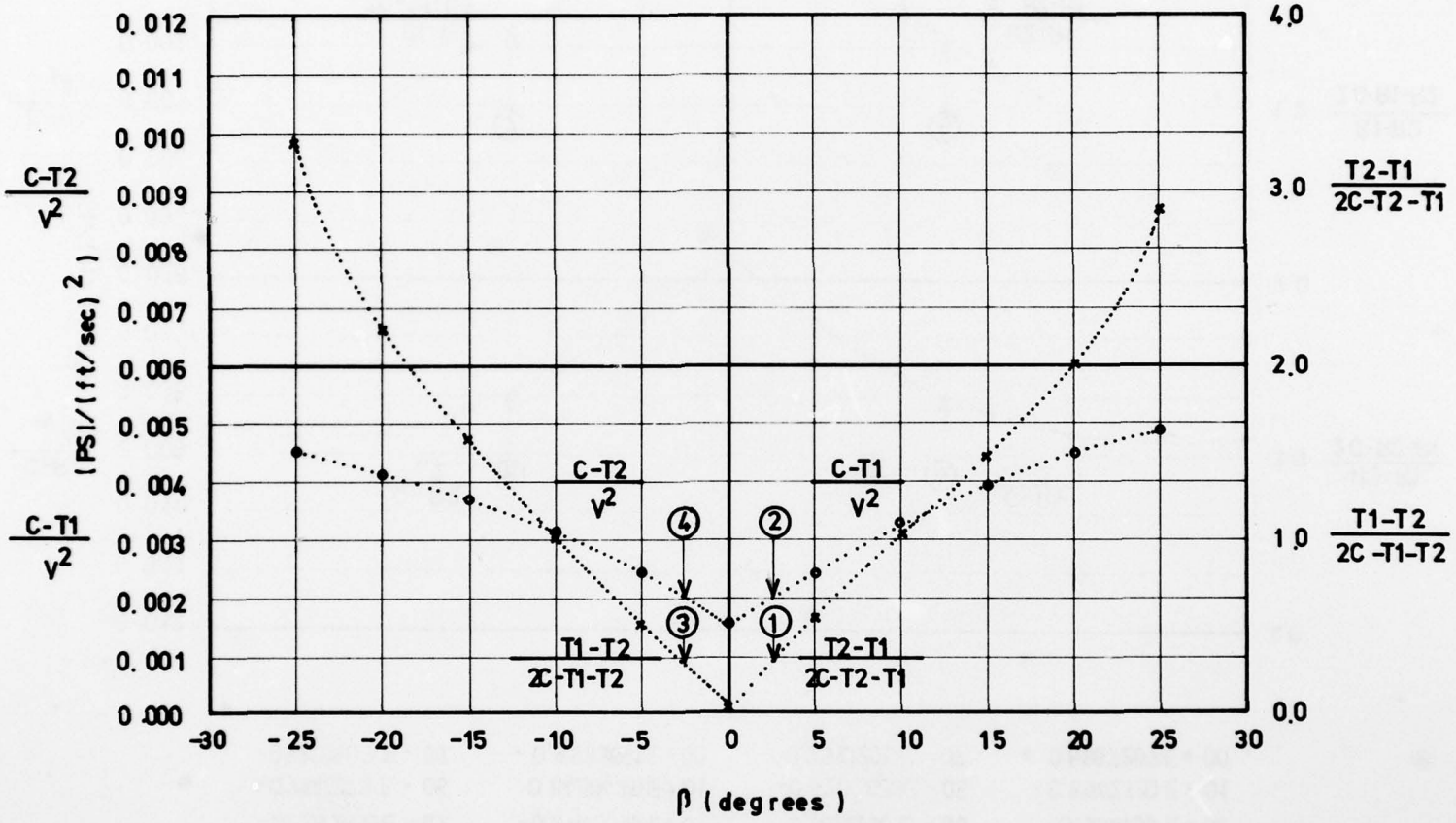


Figure 131 - Post Calibration of Tube 38 in Horizontal-Tangential Plane holes 7.6.8.3.11

⑧ 0.1461651E - 02	⑦ 0.3522949E + 00	⑥ 0.1455996E - 02	⑤ -0.6096191E + 00
-0.1729950E - 03	-0.1169678 E + 02	0.1812279 E - 03	0.1175293 E + 02
-0.1473818E - 05	0.9016113 E + 00	-0.1732726E - 05	-0.1125488 E + 01
0.1468288E - 07	0.4081726E - 01	-0.1973240E - 07	-0.6103516 E - 03

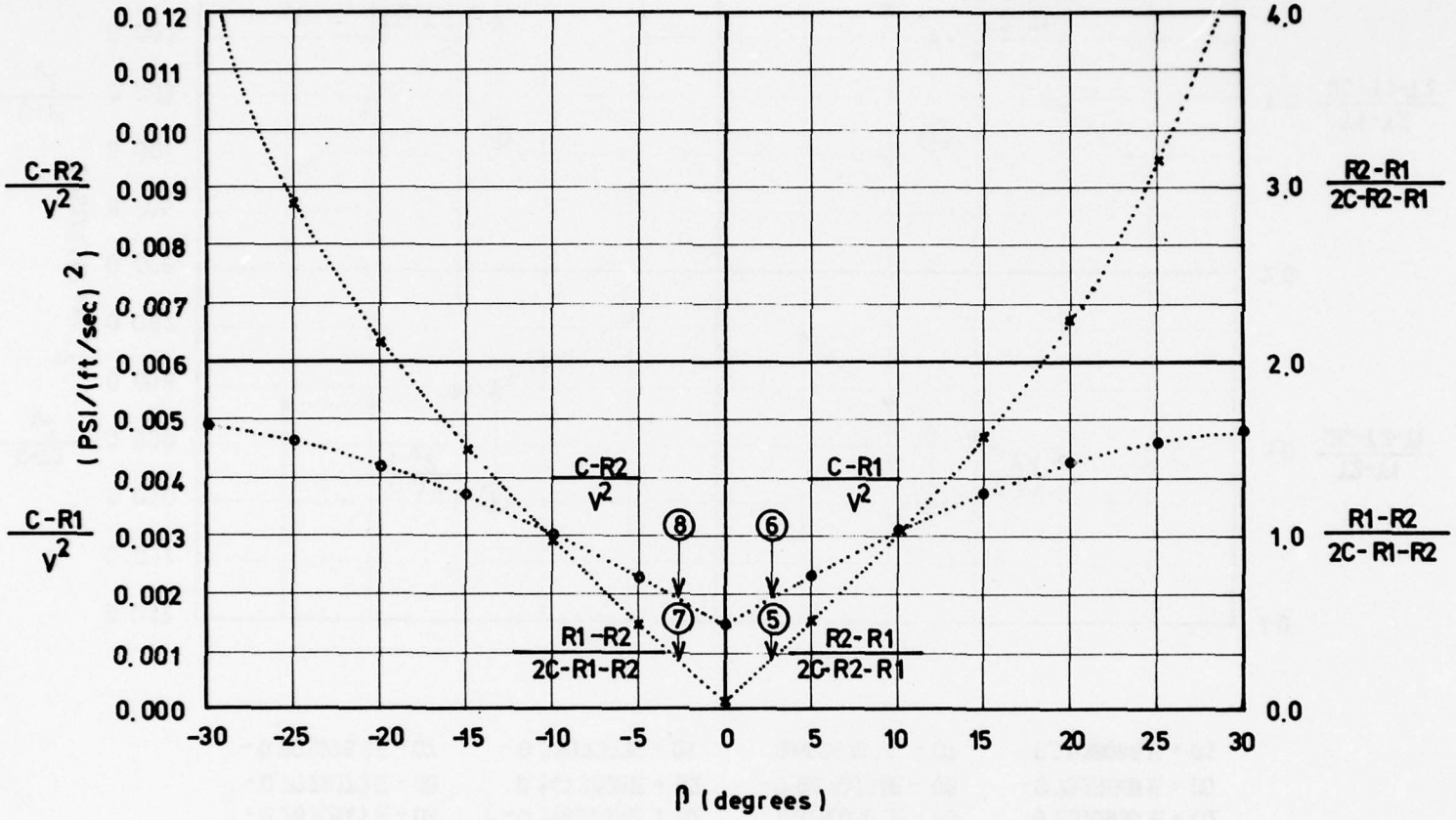


Figure 132 - Post Calibration of Tube 38 in Vertical - Radial Plane holes 7.6.8.3.11

④ 0.5631983E - 02	③ 0.9938960E + 00	② 0.5643725E - 02	① -0.9575195E + 00
-0.2632141E - 03	-0.3185156E + 02	0.3460050 E - 03	0.2310938 E + 02
-0.7022172E - 05	0.1473828E + 02	-0.9670854E - 05	-0.7929688 E + 00
-0.3036985E - 07	-0.3307373E + 01	0.6891787 E - 07	-0.2038086 E + 01

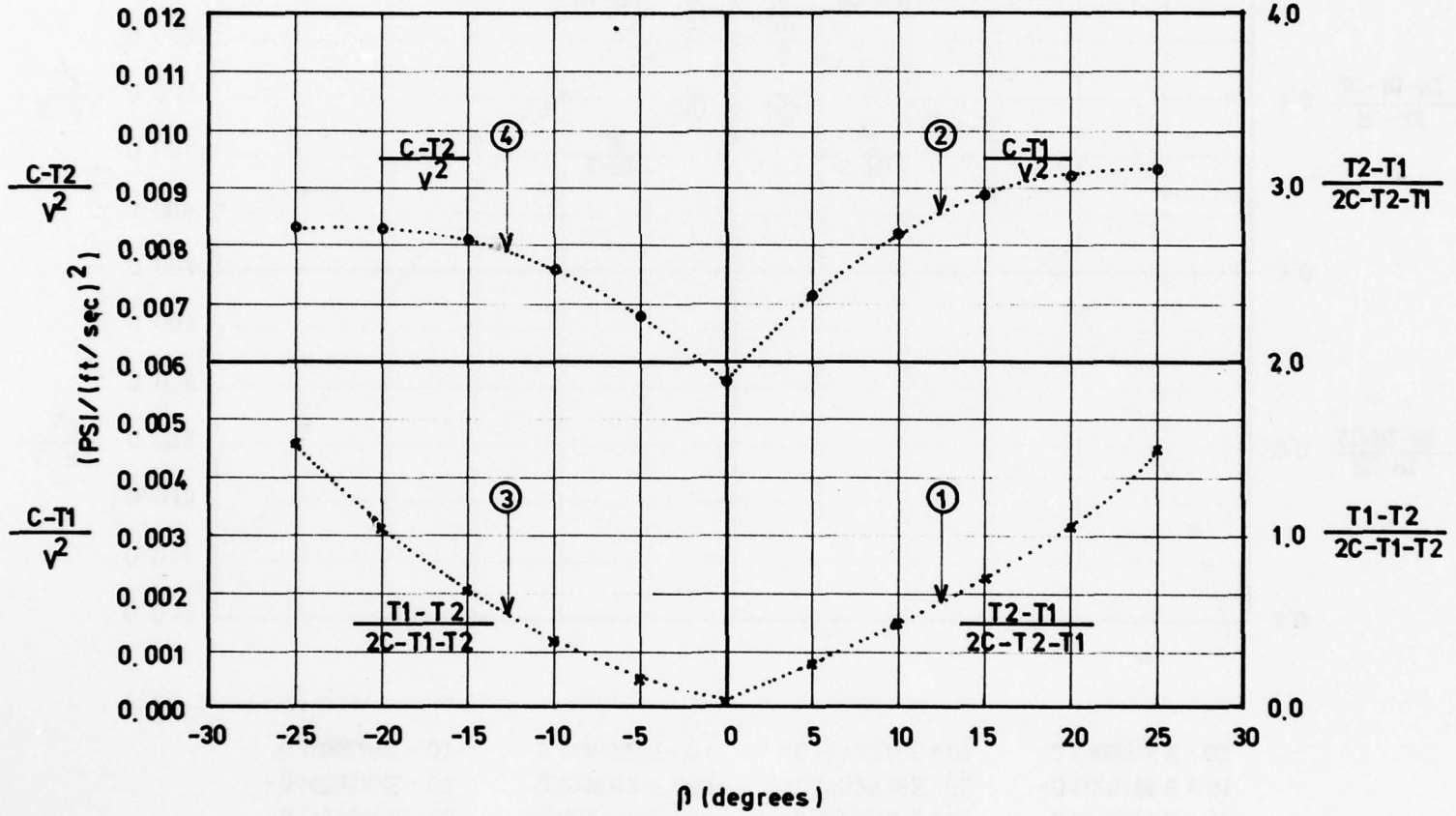


Figure 133 -Post Calibration of Tube 38 in Horizontal-Tangential Plane holes 7.5.9.1.13

⑧	⑦	⑥	⑤
0.5859554 E-02	0.9794922 E+00	0.5873203 E-02	-0.8283691 E+00
-0.1170635 E-03	-0.3453125 E+02	0.2492666 E-03	0.2301562 E+02
0.1227856 E-04	0.2143750 E+02	-0.4172325 E-06	0.2304688 E+01
0.8118805 E-06	-0.9500000 E+01	-0.2719462 E-06	-0.6742188 E+01
0.1279113 E-07	0.1800781 E+01	0.4714821 E-08	0.1785156 E+01

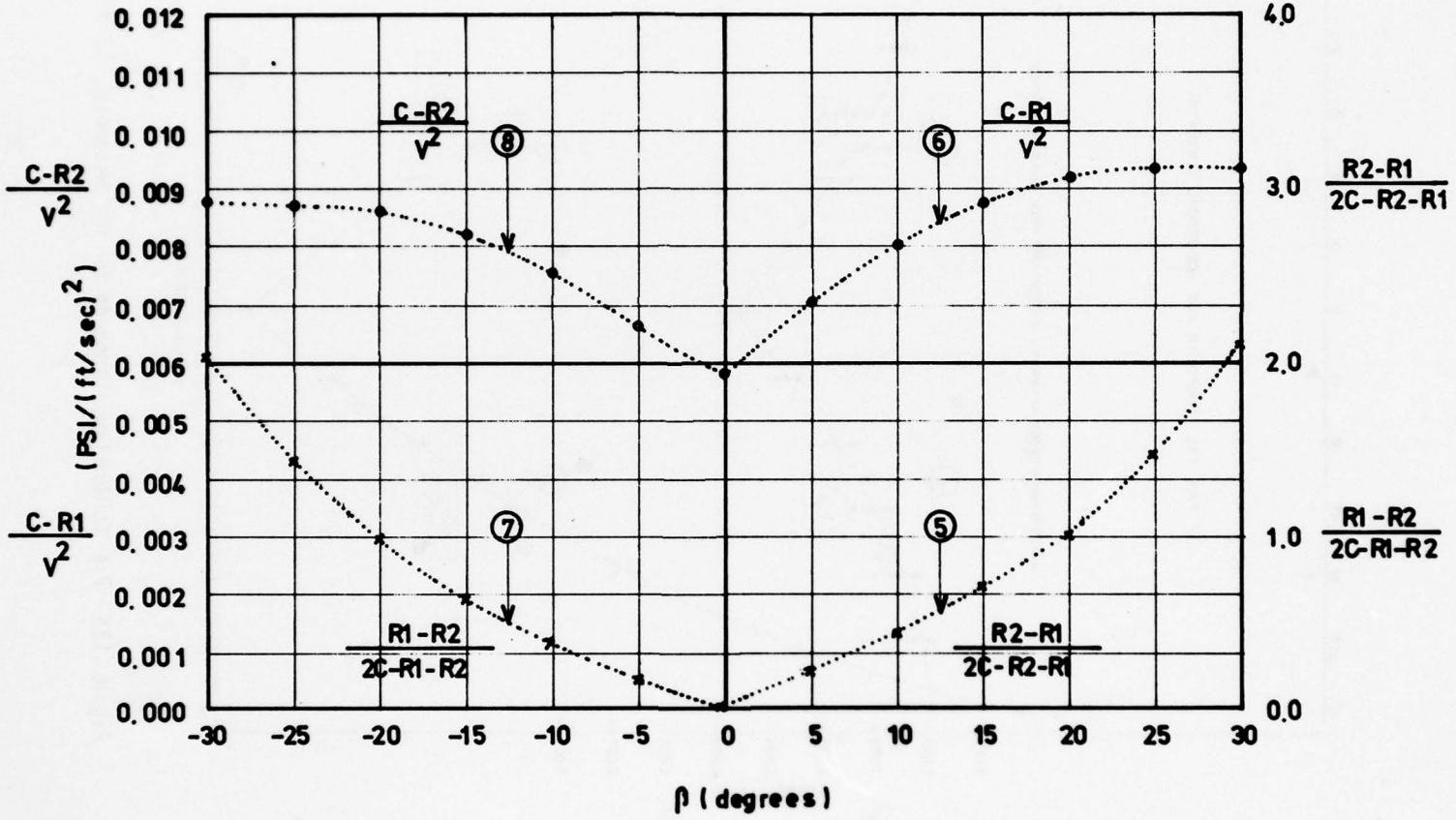


Figure 134 - Post Calibration of Tube 38 in Vertical-Radial Plane holes 7.5.9.1.13

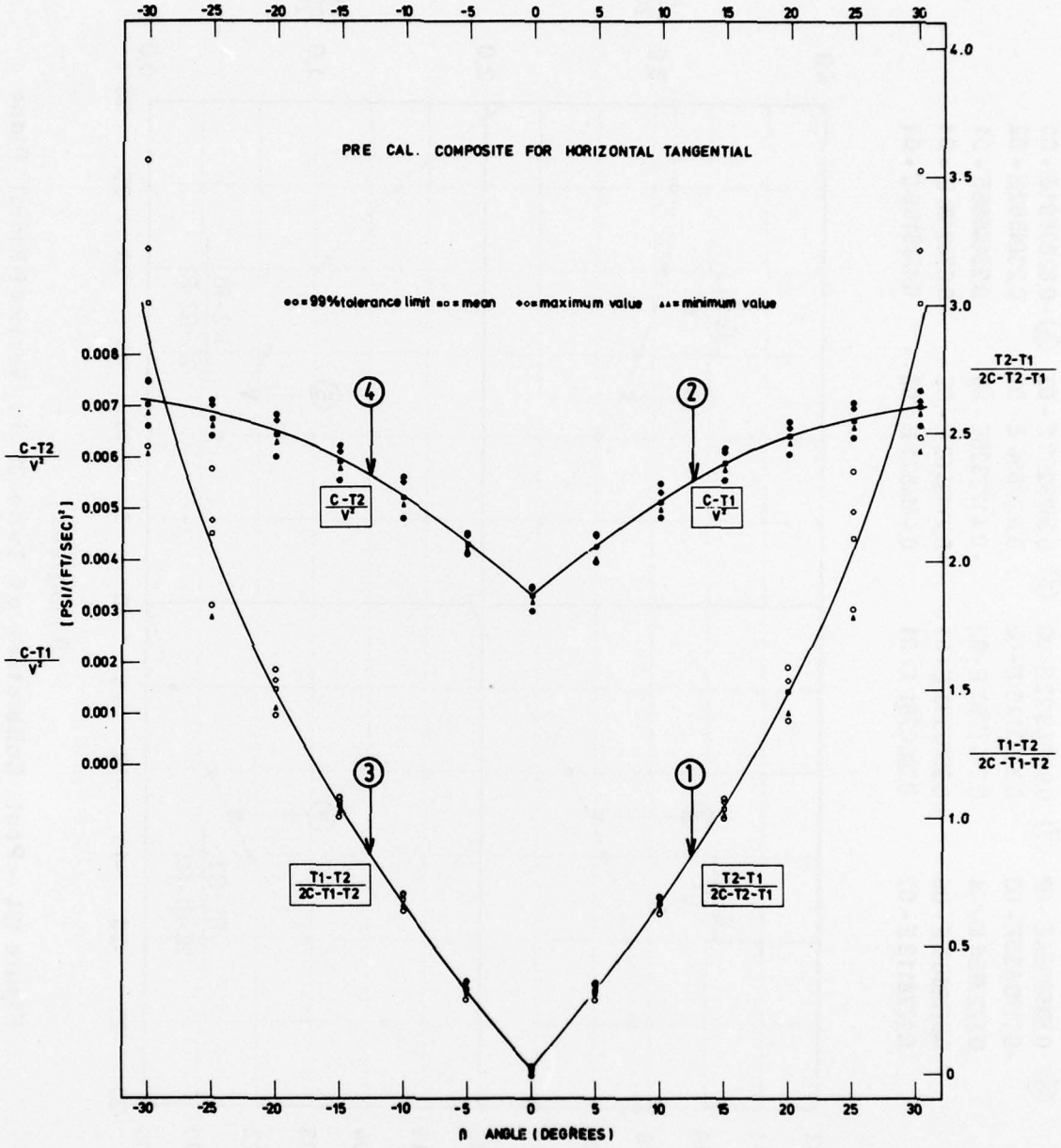


Figure 135 - Pre Calibration Composite for the Horizontal/ Tangential Plane

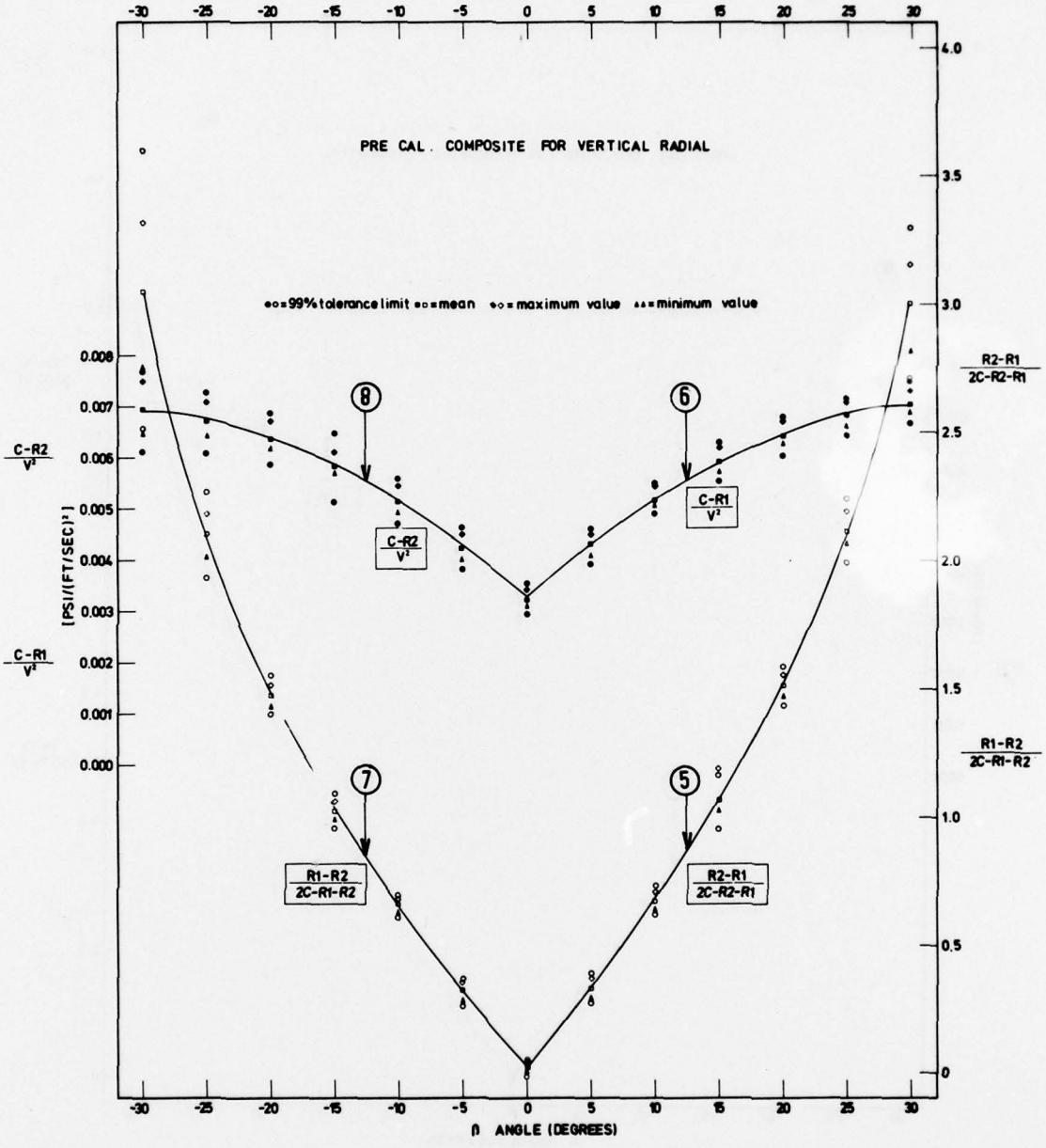


Figure 136 - Pre Calibration Composite for the Vertical / Radial Plane

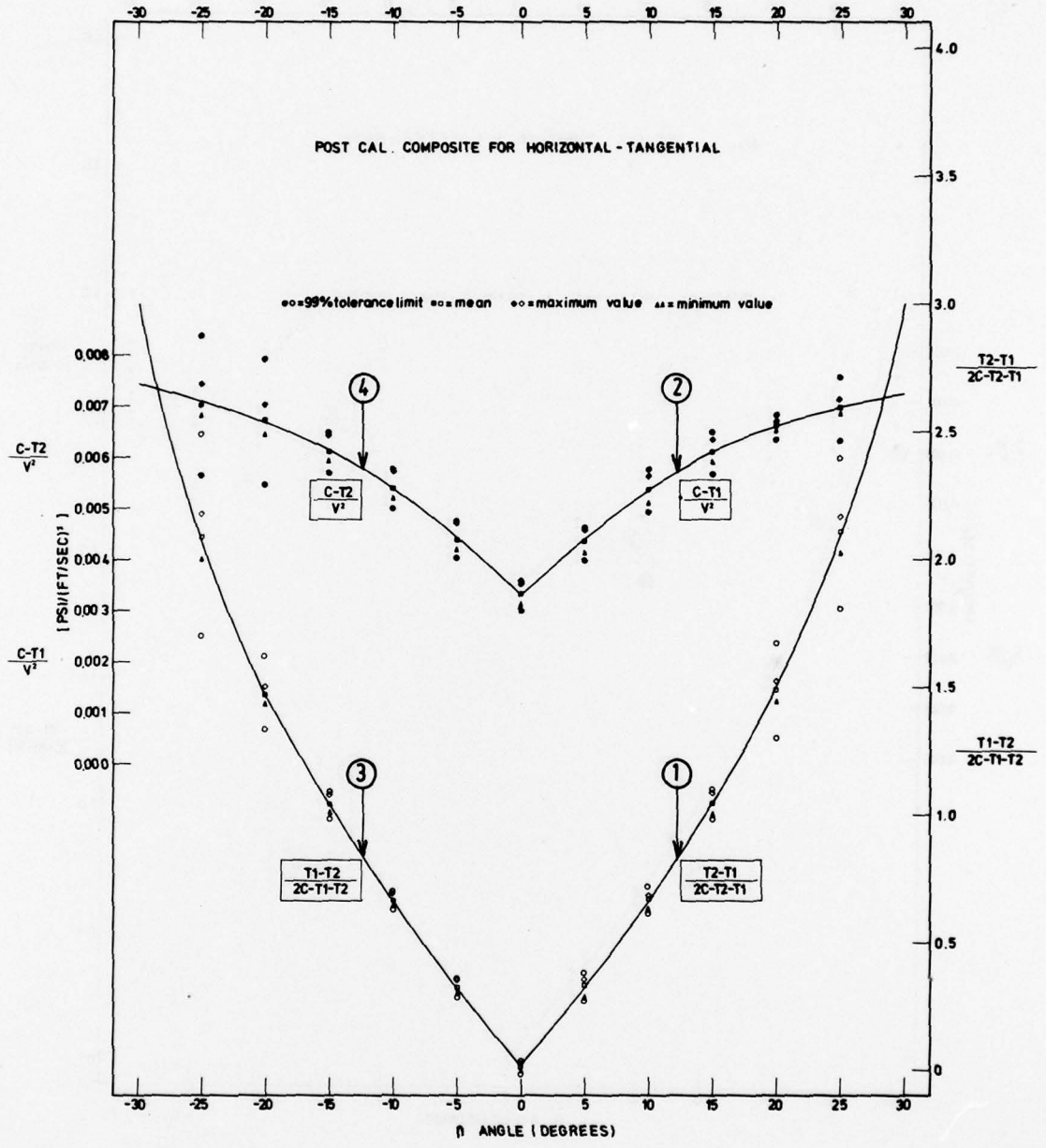


Figure 137- Post Calibration Composite for the Horizontal/Tangential Plane

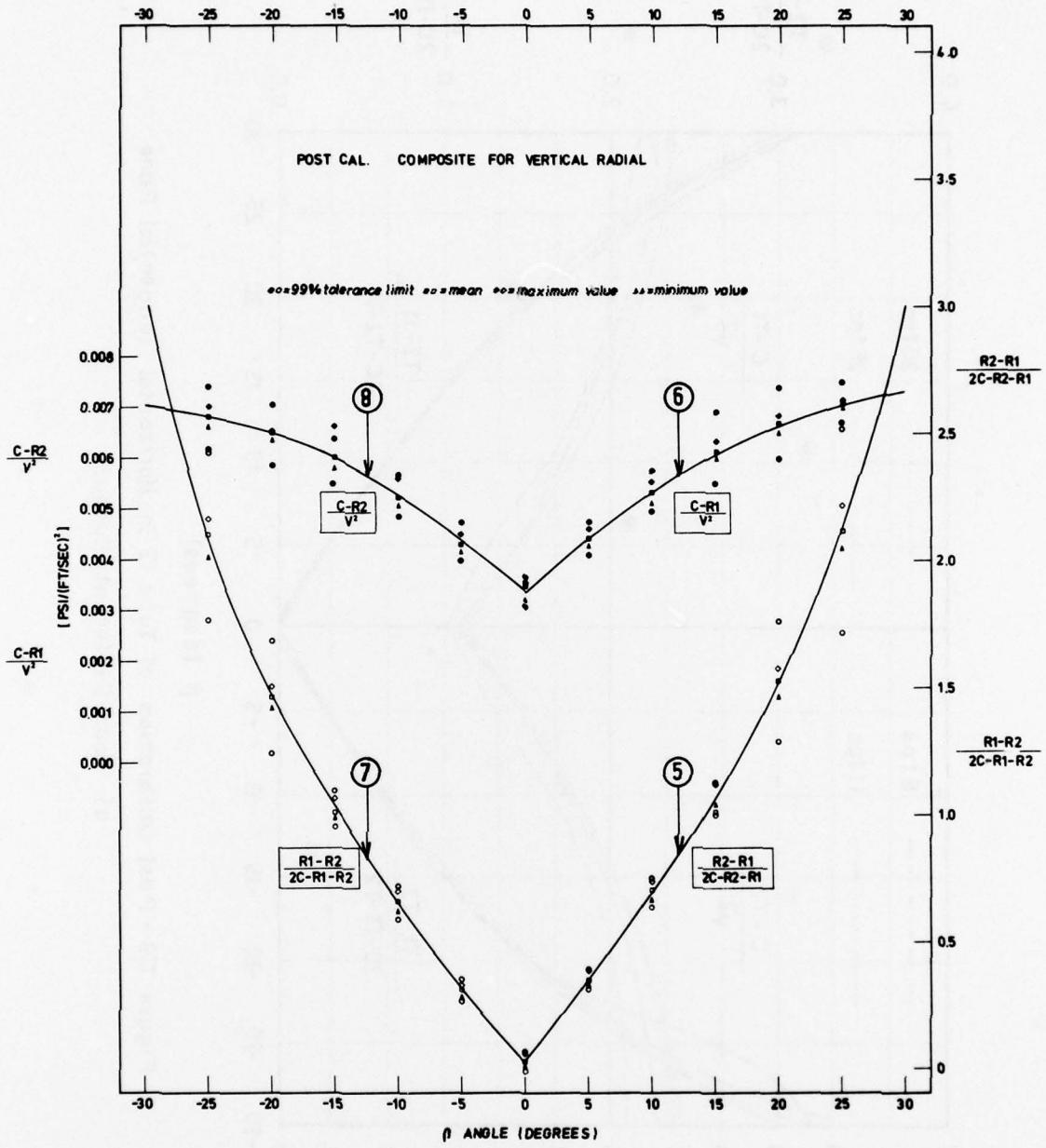


Figure 138 -Post Calibration Composite for the Vertical / Radial Plane

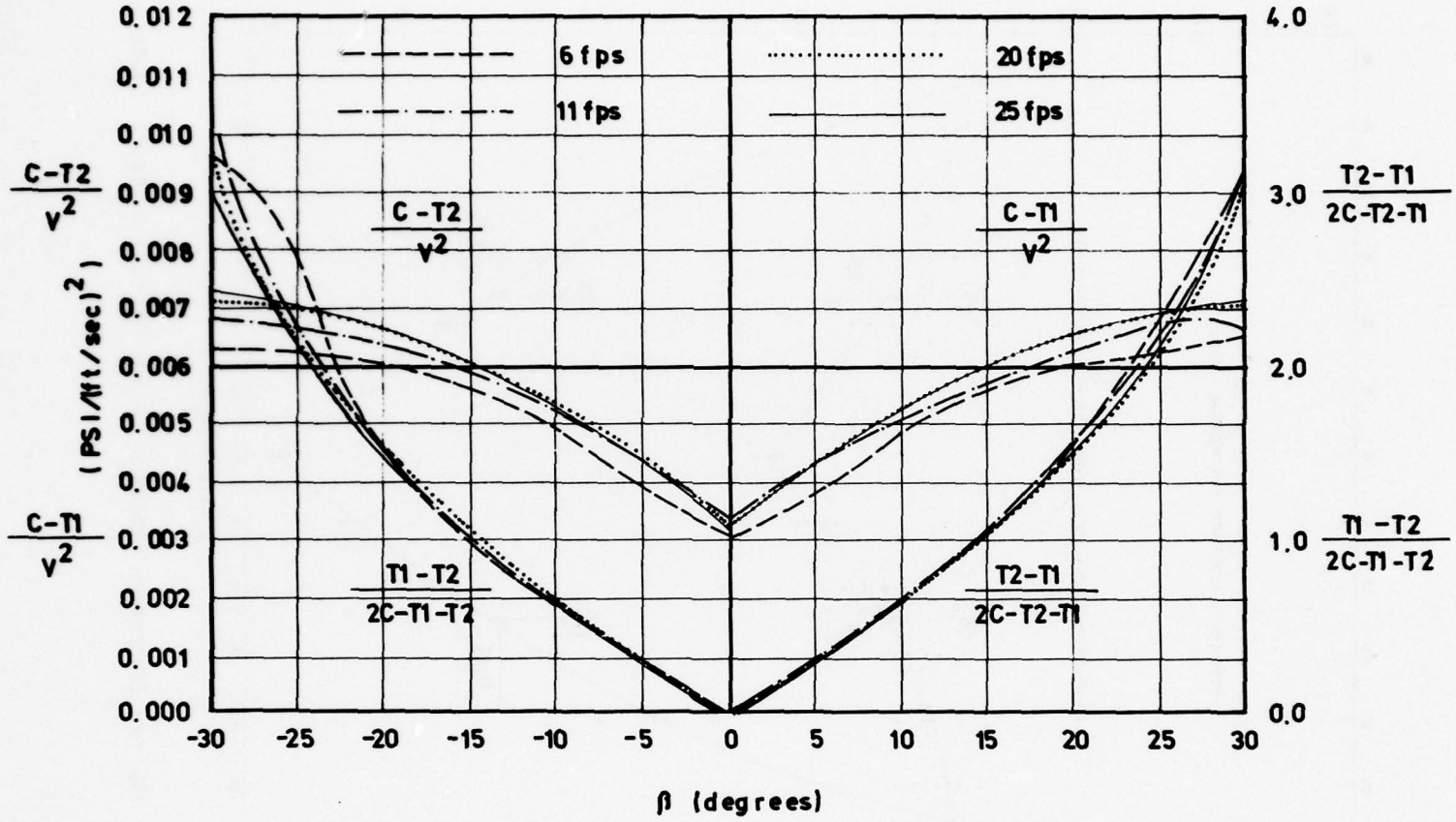


Figure 139 – Post Calibration of Tube 13 in Horizontal-Tangential Plane at Four Different Speeds

APPENDIX A

PROCEDURE FOR DERIVING VELOCITY COMPONENT RATIOS FROM PRESSURE MEASUREMENTS

Column	Identification	Derivation
1	C-T1	Pressure at hole C minus pressure at hole T1, converted to inches of water pressure.
2	C-T2	Pressure at hole C minus pressure at hole T2, converted to inches of water pressure.
3	T2-T1	= (C-T1) - (C-T2) = Col. 1 - Col. 2
4	2C-T2-T1	= (C-T1) + (C-T2) = Col. 1 + Col. 2
5	$\frac{T2-T1}{2C-T2-T1}$	$= \frac{(C-T1) - (C-T2)}{(C-T1) + (C-T2)}$ = Col. 3 / Col. 4
6	β_{LT}	Angle of water flow in the LT plane. Read from calibration curve at value of $\frac{T2-T1}{2C-T2-T1}$ in Col. 5. If the value of Col. 5 is negative, read the curve labeled $\frac{T1-T2}{2C-T1-T2}$.
7	$\frac{C-T1}{V_{LT}^2}$	Read from calibration curve at value of β_{LT} in Col. 6, if the value of Col. 5 is positive. Otherwise, omit.
8	$\frac{C-T2}{V_{LT}^2}$	Read from calibration curve at value of β_{LT} in Col. 6, if the value of Col. 5 is negative. Otherwise, omit.
9	V_{LT}^2	$= \frac{C-T1}{(C-T1)/(V_{LT}^2)}$ = Col. 1 / Col. 7 if Col. 5 is positive, or $= \frac{C-T2}{(C-T2)/(V_{LT}^2)}$ = Col. 2 / Col. 8 if Col. 5 is negative.
10	V_{LT}	Component of the water velocity in the LT plane. $= \sqrt{V_{LT}^2}$ = square root of Col. 9.
11	$\cos \beta_{LT}$	= cos of angle in Col. 6.

Column	Identification	Derivation
12	$\sin \beta_{LT}$	= sin of angle in Col. 6.
13	V_{L_1}	Longitudinal component of the water velocity derived from V_{LT}. $= V_{LT} \times \cos \beta_{LT}$ = Col. 10 x Col. 11.
14	V_T	Tangential component of the water velocity. $= V_{LT} \times \sin \beta_{LT}$ = Col. 10 x Col. 12.
15	C-R1	Pressure at hole C minus pressure at hole R1, converted to inches of water pressure.
16	C-R2	Pressure at hole C minus pressure at hole R2, converted to inches of water pressure.
17	R2-R1	= (C-R1) - (C-R2) = Col. 15 - Col. 16
18	2C-R2-R1	= (C-R1) + (C-R2) = Col. 15 + Col. 16
19	$\frac{R2-R1}{2C-R2-R1}$	$= \frac{(C-R1) - (C-R2)}{(C-R1) + (C-R2)}$ = Col. 17 / Col. 18
20	β_{LR}	Angle of water flow in the LR plane. Read from calibration curve at value of $\frac{R2-R1}{2C-R2-R1}$ in Col. 19. If the value of Col. 19 is negative, read the curve labeled $\frac{R1-R2}{2C-R1-R2}$
21	$\frac{C-R1}{V_{LT}^2}$	Read from calibration curve at value of β_{LR} in Col. 20, if the value of Col. 19 is positive. Otherwise, omit.
22	$\frac{C-R2}{V_{LT}^2}$	Read from calibration curve at value of β_{LR} in Col. 20, if the value of Col. 19 is negative. Otherwise, omit.
23	V_{LR}^2	$= \frac{C-R1}{(C-R1)/(V_{LR}^2)}$ = Col. 15 / Col. 21 if Col. 19 is positive, or $= \frac{C-R2}{(C-R2)/(V_{LR}^2)}$ = Col. 16 / Col. 22 if Col. 19 is negative.

Column	Identification	Derivation
24	V_{LR}	Component of the water velocity in the LR plane $= \sqrt{V_{LR}^2}$ = square root of Col. 23.
25	$\cos \beta_{LR}$	= cos of angle in Col. 20.
26	$\sin \beta_{LR}$	= sin of angle in Col. 20.
27	V_{L_2}	Longitudinal component of the water velocity derived from V_{LR}. $= V_{LR} \times \cos \beta_{LR}$ = Col. 24 x Col. 25.
28	V_R	Radial component of the water velocity. $= V_{LR} \times \sin \beta_{LR}$ = Col 24 x Col. 26.
29	V	Model speed in ft/sec.
30	V_X/V	Longitudinal component of the water velocity expressed as a ratio of ship speed. $= 1/2 \, (V_{L_1} + V_{L_2}) / V$ = (Col. 13 + Col. 27) / (2 x Col. 29)
31	V_T/V	Tangential component of the water velocity expressed as a ratio of ship speed. = Col. 14 / Col. 29
32	V_R/V	Radial component of the water velocity expressed as a ratio of ship speed. = Col. 28 / Col. 29

V_X/V is positive in the aft direction.

V_T/V is positive in the counterclockwise direction.

V_R/V is positive toward the shaft centerline.

r/R and Θ are the polar coordinates of the point in the TR plane at which the wake is measured. r is the radial distance of the point from the centerline of the propeller shaft; R is the design propeller radius. Θ is the position angle measured from the top of the propeller disc in a counterclockwise direction.

CALCULATION OF WAKE SURVEY DATA OBTAINED WITH PITOT TUBE RAKE NO._____ MODEL_____ TEST_____

Col.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	NO.	r/R	θ	Pitot Tube
No.	C-T1	C-T2	T2-T1	2C-T2-T1	$\frac{T2-T1}{2C-T2-T1}$	β_{LT}	$\frac{C-T1}{V_{LT}^2}$	$\frac{C-T2}{V_{LT}^2}$	V_{LT}^2	V_{LT}	$\cos\beta_{LT}$	$\sin\beta_{LT}$	V_{L1}	V_T				
1															1			
2															2			
3															3			
4															4			
5															5			
6															6			
7															7			
8															8			
9															9			
10															10			

Col.	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
No.	C-R1	C-R2	R2-R1	2C-R2-R1	$\frac{R2-R1}{2C-R2-R1}$	β_{LR}	$\frac{C-R1}{V_{LR}^2}$	$\frac{C-R2}{V_{LR}^2}$	V_{LR}^2	V_{LR}	$\cos\beta_{LR}$	$\sin\beta_{LR}$	V_{L_2}	V_R	V	V_X/V	V_T/V	V_R/V
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

APPENDIX B

CALIBRATION CONSTANTS

I. FORM OF CALIBRATION EQUATION

$$Y = A_1 + A_2X + A_3X^2 + A_4X^3 + A_5X^4$$

II. CALIBRATION CURVE LABELS FOR THE HORIZONTAL/TANGENTIAL PLANE

Curve Number	X	Y
1	$\frac{T_2 - T_1}{2C - T_2 - T_1}$	β
2	β	$\frac{C - T_1}{V^2}$
3	$\frac{T_1 - T_2}{2C - T_1 - T_2}$	β
4	β	$\frac{C - T_2}{V^2}$

III. CALIBRATION CURVE LABELS FOR THE VERTICAL/RADIAL PLANE

Curve Number	X	Y
5	$\frac{R_2 - R_1}{2C - R_2 - R_1}$	β
6	β	$\frac{C - R_1}{V^2}$
7	$\frac{R_1 - R_2}{2C - R_1 - R_2}$	β
8	β	$\frac{C - R_2}{V^2}$

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.

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